Investigating Different Types of Variability in Food Production System

Ammar Noorwali

A thesis submitted in partial fulfillment of the requirements of

De Montfort University for the degree of Doctor of Philosophy

March 2016

List of publications and disseminations

NOORWALI, A. (2014) Apply MTS-MTO & Rule-based in Food Flow Processing System. *International Journal of Scientific & Engineering Research*, 5,11.

NOORWALI, A. (2013) Apply MTS-MTO and Principle Component in Food Flow Processing *International Conference in Production and supply chain management* Rome, Itlay.

NOORWALI, A. (2013) Apply Lean and Taguchi in Different Level of Variability of Food Flow Processing System. *Procedia Engineering*, 63**,** 728-734.

NOORWALI, A. (2013) Apply Lean and Taguchi in Different Level of Variability of Food Flow Processing System. *5th Manufacturing Engineering Society International Conference, MESIC 2013* Zaragoza, Spain University of Zaragoza.

NOORWALI, A., KHALIL, R. & STOCKTON, D. (2012) Investigating Types of Variability on Food Flow Processing System *International Conference on Manufacturing Research* Aston University Birmingham Aston Business School.

NOORWALI, A. (2012) Reduce High Variability Level in Food Processing. *Show case.* De Montfort University

NOORWALI, A. (2011) Mixed Types of Variability in Food processing system *Show case.* De Montfort University

NOORWALI, A. (2011) Investigate Mixed Level of Variability in Food processing system *Poster competition.* De Montfort University

Abstract

A high level of competition in the food industry, specifically in the Middle East and the UK has forced companies to improve their processes by reducing lead time, waste, and costs and increasing production efficiency.

The main challenge to the achievement of the process improvement objectives is the high level of process variability. Therefore, this research investigates the different types of variability in food production system and proposes a methodology to reduce the effect variability in food production system. The variability can be caused by several factors, for instance, in biscuit production lines variability can be induced due to short breakdown and long breakdown, variable processing times, variable temperature, etc.

The proposed approach addresses process time variability issues associated with both make-to-stock (MTS) and make-to-order (MTO) manufacturing environments using an iterated approach. The proposed methodology integrates process mapping, (which is a lean tool for identifying value added and non-value added activities), discrete event simulation (to mirror the real production line), Taguchi orthogonal arrays (to generate different scenarios in order to investigate the effect of variability on the simulation model), correlation analysis (to identify the highest variability factors), and the rule-based system (to improve food production system performance based on identified key performance indicators (KPIs)). The research uses a biscuit production line as a case study to validate the proposed methodology.

The application of the proposed approach determines that the highest effected KPI is %working. The results showed that after implementation of the rule-based system, key performance improved in high variable areas. Results analysis based on before scenario

shows that %working performance indicator is highly effected by variable temperature, speed, and breakdown factors for high variable areas such as baking, cooling, aligning, and packing. Based on identified factors and high variable areas, rules are developed by applying standardisation setting (SOP, WI, PP) in high variable areas and the results shows %working improved in baking by 4.78%, in cooling by 16.06%, in aligning by 0.35%, in packing machine1 by 2.5%, in packing machine2 by 2.37%, in packaging1 by 3.35%, and in packaging2 by 3.16%.

The integrated method allow quick response , control the environment without production interruption, reduce number of experiments , and reducing variability in high variable areas, which narrowed the improvement in the required areas and increased its effectiveness.

Acknowledgement

I would like to thank my sponsor King Abdullah bin Abdul-Aziz the former royal King of Saudi Arabia and Minister of Higher Education in Saudi Arabia, the Saudi Cultural Bureau in the UK and Ireland, the Cultural Attaché Dr.Faisal Abalkhail and his former deputy Dr.Mohammed Al-Ahmadi for sponsoring me, thus enabling me to continue my higher education including my Masters and PhD degrees. In addition, they have fully supported me in publishing my work.

I also thank my supervision team in the Centre of Advanced Manufacturing Process and Mechatronics at De Montfort University, especially Dr. Parminder Singh Kang for his help and support.

Additionally, I thank my family and my parents for supporting me during my research including my father Professor Abdulwahab Noorwali, my mother Mrs. Halema Noorwali, my wife Eng. Fatima Nasralla, my sons Mazen Noorwali and Wsam Noorwali , and my daughters Olina Noorwali and Twlan Noorwali.

Abbreviation

Abbreviation	*Description*
CLP	Constraint Logic Programming
DoE	Design of Experiment
DES	Discreet Event Simulation Model
EDD	Earliest Due Date
FGI	Finished Goods Inventory
HDDDA	Heuristic Delivery Due Date Algorithm
IDM	Integrated Device Manufacturing
JIT	Just In Time
MRP	Material Requirements Planning
MIP	Mixed Integer Program
MILP	Algorithm for Scheduling Complex Multipurpose Batch Process
MTO	Make to Order
MTS	Make to Stock
NBCC	National Biscuit and Confectionary Company
KPI	Key performance indicator
SMED	Single Minute Exchange of Dies
SPC	Statistical Process Control
%Working	It is the percentage of time when the machine is working.
%Blocked	Time when the process flow blocked.
%Waiting	It is the workstation waiting time to receive the item from previous process.
%Stopped	Time when the process flow paused.

Declaration

I declare that this thesis is original and was accomplished by me in order to achieve a PhD degree at De Montfort University and I haven't submitted before to any other universities. All efforts made by others are clearly acknowledged and referenced. I further declare I have an approval for doing this research.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Introduction

Based on researcher's previous experience working in food sector and literature review, high competition in the food industry has forced companies to reduce costs and waste and improve quality, efficiency, and utilisation. Increased levels of variability have resulted in elevated waste levels and costs and reduced quality and manufacturing process efficiency (Germain et al., 2008).

There are number of internal and external factors that can cause high levels of variability. For example, according to Van Donk (2009), correlation between products may exist and may cause the wastage of time and material due to mix of set-up time , ingerdiant, and packaging. In addition, Germain et al. (2008) assert that uncertain demand could increase the variability level of food production system as demand uncertainty could lead towards unexpected changeovers due to change in product type or quantity.

Moreover, Van der Vorst et al. (2000) consider the unplanned maintenance problems that may occur in food production system and may lead to increased manufacturing process variability and, hence, increased waste and reduced efficiency. Furthermore, based on observations of biscuit production lines, there are a number of other factors associated with food production system for instance, low oven temperature that increasing uncooked high moisture biscuits , high oven temperature that increasing burn biscuits , and lower conveyor speed that increasing biscuits jam.

Those factors are effecting increasing level of variability in biscuit production line which reflected in reduce efficiency and increase waste of time and materials (section 6.5).

The research starts with the identification of different types of production systems to facilitate the understanding of food production system (section 2.2). Then, it defines the characteristics of the food production system in order to identify the types of variability that may be associated with it (section 2.3).

Furthermore, common strategies applied in food production system. For instance, make-to-order (MTO), make-to-stock (MTS), and hybrid MTO-MTS processing are examined to shed light on the underlying processes (section 2.7) to which lean thinking could be applied and the different associated levels of variability. Then the lean tool of process mapping is applied to identify the value added and non-value added activity (section6.2) and to categorise waste (sections3.4).

The research then uses discrete event simulation (DES) to mimic the real-life environment. Section 4.5 exemplifies the DES model development and its advantages. The DES tool, Simul8, is used to develop the initial model, conduct the experiments, and implement the improvements.(section 6.6).

Subsequently, design of experiment (DoE) Taguchi orthogonal arrays are used to generate different scenarios (section 6.7) using DES then the results are correlated to identify the effect of variability in given KPIs. After the application of correlation between the variables, the highest key performance indicator performance effected KPI is found to be %working (section6.8).

The research results are then analysed using to identify the factors that affect %working. For process improvement, the rule-based approach (an artificial intelligence tool) is employed to reduce the effect of factors that decreased working (section 6.9).

The results show that, after the implementation of the proposed approach, the selected KPI, increasing working and throughput and reducing waste. %working improved in high variable areas .In addition, precess stability increases with the reduction in variability, Section 7.2. Moreover, customer fulfilment improves as the reduction of the waiting time ensures that the product reaches the customer on time. The research

1.2 Problem statement

Numerous researchers apply process improvement to reducing the effect of variability on food production system. For example, Kopanos et al. (2011) apply the mixed integer program (MILP) to improving the yogurt lot sizing problem by reducing changeover time and increasing utilization. In addition, Ierapetritou and Floudas (1998) apply the mixed integer liner program (MILP) to reduce machine breakdown and labour change. However, they focus on reducing the varibility of lot sizing and scheduling without any consideration for production problems. Researchers has used numerous techniques i.e. simple techniques such as lean six sigma tools such as 5s , process mapping , seven types of wastes, pareto charts , integrated complex methods GA and simulation (Kang, 2015, Kang 2012), and Nural netwroks etc. However, reducing the effect of variability is still a key challenge because diffrent level of variability affected by different factors (section 1.1) need to be considered to apply improvement in high variable areas.

To develop the case study and understand the process, the research is observed closely and the biscuit production line's performance is measured (section 6.3). It is observed that, due to a high level of variability in biscuit production line 12, there is an increase in both time and material wastage. For example, section 6.3 shows waste of time and material in biscuit production line.

Thus, the research focuses on reducing variability in food production system.

The proposed approach is validated using a real-life scenario, which is implemented in the National Biscuits and Confectionary Company (NBCC). The factory has fifteen production lines that produce more than sixty products (biscuits and snacks).

Many factors cause this high level of variability, for instance, machine breakdown and variable temperature in different production areas (such as the baking, cooling, and packing areas). Thus, the research needs to consider these factors to improve the process, reduce the wastage of time and material, and increase production stability.

1.3 The aim and objectives of the research

The aim of the research is to reduce the effect of process time variability in food production system. The research objectives follow:

- To illustrate the types of production so as to facilitate the understanding of the food flow processing system,
- To highlight the generic characteristics of food production system so as to help identify different types of variability in food production system,
- Understanding the effect of variability in MTS-MTO food production system by determining the effect of variability on given KPIs,
- Root cause analysis to identify the main cause of variability,

- Development of an integrated approach to reduce the effect on variability for hybrid MTS-MTO food production systems,

- Development of a process improvement methodology to address the different problems in food production system,

- To identify the higsht effected KPI and define the factors that increasing variability on the effected KPI,

- To apply process improvement to improve the highest variable areas using the artificial intelligence tool, the rule-based system,

1.4 The structure of the thesis

Chapter 2 illustrates food processing systems and the characteristics of food processing in order to identify the value added and non-value added activities. Second, it identifies different types of variability in food production system. Third, the chapter narrows the literature review down so that it covers MTS, MTO, and a hybrid MTS-MTO system and then defines opportunities for adopting lean in food production system.

Chapter 3 illustrates the adoption of lean thinking in the food industry and measures the levels of variability possible among the food processing workstations. Chapter 4 highlights the existing measures applied in food production system to identify the best approach for the research. Chapter 5 describes some of the qualitative and quantitative research methods to facilitate the choice of a clear path for the research topic.

Chapter 6 illustrates the different steps taken, including process mapping, a simulation model, and correlation analysis. In addition, the research explores Taguchi orthogonal arrays in the measurement of variability in food production system. To implement improvements, the research applies an artificial intelligence tool, the rule-based system, to reduce variability in food production system. Chapter 7 analyses the results to measure the factors' effect. In addition, it highlights key performance indicators and process improvement. Chapter 8 constitutes a discussion. Chapter 9 draws conclusions, makes recommendations, and outlines future work possibilities.

Chapter 2: Food Processing System

2.1 Introduction

Food production system is the process of producing food products, starting from raw materials, and ended in finished goods through a number of processes in production system based on the customer demand and specifications. Therefore, the materials flow through the manufacturing process towards customer requests at the required specification with minimum waste to maximum utilization and at minimum cost.

This chapter will first identify types of production systems in order to clarify different types of variability that might affect the operational performance. Therefore, food production system characteristics are highlighted to identify the different types of variability. Furthermore, this chapter investigates food production system strategies, in order to identify the improvement opportunities. Lean implementation is one of the key objectives of this research therefore, process improvement opportunities are exemplified from the aspect of lean philosophy i.e. identification of waste in food production system and use of Lean tools to understand the added value and non-added value activities.

2.2 Types of production systems

In order to reduce variability in production, it is important to understand the food production system in context of different production systems. Therefore, this section will emphasize different types of production systems and explicitly relate these to the food production system.

Production systems can be divided based on the product variety and quantity, which are (Khalil, 2005):

- *Job shop production;* a high range of products with a very low demand level, different batch sizes can be produced within a process orientated facility layout. For example, canteen production has high range of products with very low demand level.

- *Batch Production*; a high range of products of low to medium demand level**,** a small batch size or one item can be produced within a process orientated facility layout before switching to the batch of other product. This usually involves the setup between different batches. For instance, cake production, the production line produce different types of cake shapes and flavours depend on the customer demand.

- *Continuous processing;* a low range of products with a very high demand level, one product is produced through a continuous product oriented facility layout. For example, crisp production has low range of products with a very high demand level.

- *Flow production;* a low range of products of medium to high demand level, a small numbers of product types or large batches of one product are produced through a product oriented facility layout. For instance, soft drink production producing low range of products with medium to high demand level.

The research applied a case study on a biscuit production line using continuous processing, as exemplified in section 6.3.

For instance, continuous production system doesn't have variability from the product variety. However, process time variability still can occur from machine breakdown this can cause waste of time and materials as mentioned in section 6.5.

In order to find opportunities for applying lean in food production system, the research highlights some common strategies that are applied in food production system systems.

2.3 Generic characteristics of food production system

After identifying types of production systems, the research would identify characteristics of food production system in order to recognize different levels of variability in food.

According to Akkerman and Van Donk (2009), food production system mostly consists of three stages input, process, and output and between these stages intermediate storage is present. Thus, the research highlighted the characteristics depend on these three areas.

2.3.1 Input

- *Raw material*; According to Van Donk (2001), the nature and basis of raw material frequently entails an uncertainty in supply, quality and price due to variable yield of farmers. The uncertain supply and quality of raw materials may cause lack of synchronisation and increase interruption between processes .The process may produce out of standardisation products and that may affect with the flow of materials. E.g. in biscuit production different types of flour may affect the product quality.

- *Weather changes*: according to Lund, D (2003),weather changes affect last minute orders for instance; from the research previous experience the weather gets cold the customers may order more biscuits and that affecting with planed forecast and increase process variability.

- *Poor capacity planning*; Van Wezel et al. (2006) stated that production planning and control systems comprise two activities: control of materials and planning for capacity. These two activities must be coordinated based on external (customer demand, market requirements, etc.) and internal variability (product mix, process/resource variability, etc.). Food processing systems are associated with variability and unstable customer demand, it is difficult to estimate capacity requirements far enough into the future to fulfil market requirements.

- *Packing specification*; as there are mixed types of products processed simultaneously, it is difficult to switch from one product to another, especially in the packing stage. According to Van Donk (2001), as the range of food products is very wide and sometimes changing from one product to another requires changing the dimensions of packaging, there is conflict in switching between products which can increase set-up time.

2.3.2 Process

- *Process features;* process features include processing time, breakdown, and variable setting (i.e. temperature, speed). According to Van Donk (2001) these include long (sequence-dependent) set-up times between different processes in some cases; there may be long setup times between different processes that could cause high levels of variability. For instance, in a biscuit production line, increasing the cooling conveyor speed may increase variability in the packing machine. In addition, machine breakdown may increase waste of time and material. For example , in biscuit production line , if packing machine stopped working , that may increase waiting and biscuits wastes in packing , cooling , and baking.

- *Product mix*; *as Van Donk* (*2001) illus*trated, there are numerous mixed products or even processes until a complete order or product is finished. For example, changes between two types of biscuits. Each type has different ingredients, processing times, and machine settings (e.g. oven temperature, etc.) i.e. variability induced due to these factors may lead towards increased setups, hence, non-value-added activities.

- *Automation;* according to Van Donk (2001) many food processing industries are shifting towards automation as that may reduce time and materials wastage. For example, automation in aligning and packing in biscuit production line However, there are still some areas that require labour such as packaging.

2.3.3 Output

- *Lead time;* it is important in the food industry as the product should be available on the market shelf on time. Therefore, a fulfilment order release plan and dispatch control is essential to fulfil customer demand according to agreed delivery dates. The release plan certifies that the order is not released too early or too late, while the dispatching control aims to accelerate late orders to achieve on time delivery, for instance in food processing.

- *Limited shelf life:* According to Soman et al. (2004), shelf-life products may limits the use of intermediate stocks and finished product inventories to minimize the effect of variability and fulfil the customer demand respectively.

Thus the research stated characteristics of food production system in order to identify different levels of variability in food production system. Out the characteristics identified in this section, current research will focus on process feature in biscuit production line such as machine breakdown, variable temperature setting, and variable conveyor speed.

2.4 MTS and MTO overview

The research highlight common strategies applied in food such as make-to-order (MTO) and make-to-stock (MTS).

According to Soman et al. (2006), the new business model uses telephone/internet ordering and the requirement of a quick response service increases implementation of make-to-order (MTO) that encourages production to be oriented to satisfy specific demands. Soman et al. (2006), mentions make-to-order (MTO) produce to fulfill customer demand. This could be due to highly irregular demand, customized products, trail products, tendered products, or very short shelf life products.

However, make-to-stock (MTS) is still needed for standard products, such as <example. Thus, due to food's irregular demands, current research may consider MTO and MTS as strategies that may commonly be used in the food environment. The research will identify MTS and MTO and then highlight the characteristics of both in order to find opportunities to apply improvement in food production system.

2.5 MTS Definition

According to Zaerpour et al. (2008), the MTS system is producing finished or semi-finished products based on the demand forecast and then item are stocked to fulfill the customer demand. Youssef et al. (2004) states, under MTS management the items are produced in prediction of future orders and stocked in the Finished Goods Inventory (FGI).

Moreover, Cattani et al. (2003) defines the MTS strategy as "*pre-build a standard product using efficient capacity in advance of single uncertain demand event*".

In summary, the research here can define MTS in food according to the above definitions as producing products and stocking them in an FGI based on demand forecasts and the pulling level of inventory to increase flow in the food production system.

For example, biscuit production line produce some types of biscuits i.e. hard biscuits to stock them and then sell them to the customer as hard biscuits has long shelf life.

2.6 MTO Definition

Zaerpour et al. (2008) stipulates, the MTO system is produced only when a customers' demand is placed.

Youssef et al. (2004), interprets the MTO process as, "*a production order is released to the manufacturing facility only after the firm demand has been received*".

According to Claycomb et al. (2005), "*in MTO manufacturing or assembly is undertaken after the order is received as the product is customised to meet the customer preferences*".

Furthermore, Cattani et al. (2003), defined the MTO strategy as "*a strategy to acquire more expensive flexible capacity that can produce after observing the demand event*".

According to the above, the research can define MTO in food, as the manufacturer only produce the product after the order has been released, in order to increase the product value stream in a food production system.

For example, if the customer orders different types of biscuits i.e. sandwich biscuits that filled with cream, then the production start produce them based on the customer demand as they need to be stored in the fridge. Thus, store them in the warehouse for long time consider to be cost effective.

2.7 MTS and MTO characteristics

From the definitions, MTS and MTO characteristics can be given as in table 3.1. These can be exemplified based on the inventory, cost, production, customer demand and scheduling.

Table 2.1 Illustrates a comparison between MTS and MTO Characteristics

(Kaminsky and Kaya, 2009); (Zaerpour et al., 2008); (Soman et al., 2004);(Cattani et al., 2003); (Soman et al., 2006);(Wu et al., 2008))

	MTS	**MTO**
Inventory	Kaminsky and Kaya (2009) considered the MTS system as "push" system that has high level of inventory. For example, producing hard biscuits to store them as they have long shelf life.	According to Zaerpour et al. (2008), the MTO system removes finished-goods stock as the order is dispatched to the customer after being produced. Kaminsky and Kaya (2009) mention that MTO system is considered as a "*pull*" system which minimises the inventory level. For example produce sandwich biscuits based on customer demand as store them in the fridge

		for long time consider being cost effective.
Cost	According to Soman et al. (2004) while MTS is producing in high capacity, the product cost is low. However, to Zaerpour et al. (2008), MTS has become expensive in a large number of products. For example, mixed of sandwich and hard biscuits.	Cattani et al. (2003) noted that using the MTO flexible system in production lines helps to reduce the expense of extra costs. However, responding to exact customer demand needs flexible resources and better planning as MTO systems are more vulnerable to the failure due to last minute orders and demand changes. For instance , weather change may affect on customer demand (section 2.3.1)
Product-ion	According to Cattani et al.(2003) operating in the MTS system helps to increase production utilization by running long-term production lines in high capacity as the plan will be for producing to stock. This makes planning processes easier and more predictable. For instance, long running of biscuit production line can reduce oven temperature variability.	MTO has flexibility in product mix to produce as high a range of products as it produced after the order is released. Therefore, the production schedule needs to be more flexible in order to respond to the customer demand. For example, producing different flavours of sandwich biscuits based on customer demand.
Demand	According to Soman et al. (2006), MTS products depend on forecasting by knowing in advance how much should be produced. Youssef et al. (2004) mentions the MTS benefit are to enable immediate reactivity to external	According to Kaminsky and Kaya (2009), the demand will be according to the customer's requirements instead of forecasts. Some fresh food products commonly produced based on customer demand (section2.3.1).

	demands. Long shelve life food products such as hard biscuits commonly produced based on forcasting.	
Scheduling	Wu et al. (2008) states that the main key performance in scheduling of MTS products is *throughput*. For instance, when the factory producing hard biscuits with long shelve life to stock, then the main key performance is throughput.	According to Wu et al. (2008), the main key performance in scheduling of MTO products is the "*on time delivery rate"*. For instance, producing sandwich biscuits with short shelve life and expensive refrigerated storage; the main key performance is delivery rate.

From the above points, the research found that the combination of both MTS and MTO in food production system may impact as the following:

- A reduced level of inventory; applying MTS to the inventory guard against variability and increases stability. On the other hand, MTO provides flexibility. Thus, combining them may reduce the inventory level and provide ability to react towards customer demand. Lean pull production approach might be applied to reduce the inventory level.

- Reduction of costs; MTS enables production of products at lower cost and MTO helps to reduce extra costs by applying flexible production system. Thus, the combination may reduce costs in food and that can give a competitive advantage, which is the main drive for lean implementation.

- Improve production optimization; applying MTS helps to increase production utilization and applying MTO helps to increase production flexibility. Thus, the combination of MTS-MTO can provide production optimization by allowing increased utilization and flexibility.

- Satisfy customer requirement; MTS depends on demand forecasting and MTO is based on the customer orders. Therefore, applying MTS-MTO may satisfy the demand for standard and customer specific demand. In addition, the Lean principle specifies value can be applied for increased customer fulfillment.

- Improve scheduling utilization; irregular food demand increases variability in scheduling. Thus, applying a combination of MTO-MTS may increase scheduling utilization by producing products to stock and to fulfill customer demand.

The research will use biscuit production line as a case study. Biscuit production considered as continues production system which is MTS based system as the production produce to stock. However, hybrid of MTS-MTO may applied based on customer demand.

2.8 Recent trends, moving from MTS to hybrid MTO-MTS.

According to Soman et al. (2007) due to increased product range with reduced lead time, companies are forced to shift from MTS to MTO in order to fulfill customer requirements. As mentioned in section 2.6 producing with MTS may increase the inventory cost as the factories require storing these products for long time. In addition, as Youssef et al. (2004) stated, the downside of the MTS management system is the inventory holding cost, connected with the FGI.

However, there is still a need for MTS in some industries, such as long shelf life food products, that have a very low variable demand and more stability. In addition, it is economically beneficial to produce these products to stock rather than producing them to order. Soman et al. (2007) mentioned that there is a need of economic production using stable repetitive cycles along with flexible schedule planning that can react with variable customer demand. This combination makes companies move supplementary to use both MTS-MTO which is called a hybrid MTO-MTS strategy. MTS and MTO can be helpful in food production system for demand satisfaction, inventory, and cost reduction.

Soman et al.(2004) exemplified that the hybrid MTS-MTO strategy can be applied in many industries such as: electronics, automotive and food production system. According to Soman et al. (2004), the combination of MTO and MTS is quite common in the food production system. Food production system companies have to consider the requirement for customer fulfillment in very competitive market due to:

- Increased number of products with customer specific characters, special packing requirements, etc.
- To increase or maintain of the market share.
- Sellers and wholesalers to anticipate small shipments within short and reliable time windows. At the same time, they do not accept two subsequent shipments with the same due dates,
- The companies are required to be flexible in their response with changes of customer's behavior.

2.9 Variability

This section will define variability and identify types of variability that may affect the food production system.

Hund et al. (2001), defined variability as "*a parameter associated with the result of a measurement that characterises the dispersion of the value that could reasonably be attributed to the measured*".

Hopp and Spearman (2001) defined variability as "the *quality of non-uniformity of class entities*". For instant, in a group of individuals if their weight is exactly the same, then there is no variability in weight. On the other hand, if the weight is different, then there is variability in weight.

According to Germain et al. (2008) the variability can be defined as "*the level of inconsistency in the flow of goods throughout the company*". For example, different types of biscuits (variable customer order), can cause variability in raw material, process parameters, etc.

As Khalil (2005) mentions, variability is a natural phenomenon that happen everywhere and that include manufacturing environments. Thus, it is difficult to define the cause of it exactly.

From the above, the research can describe variability in food as the dispersion that can happen naturally everywhere in food production system.

2.10 Different types of variability in food production system

According to the literature review and food production system characteristics, MTS-MTO, and variability definition in sections 2.3 and 2.4 respectively, the research here has identified a brief list of types of variability that may affect food production system.

- *Product mix;* According to Akkerman and Van Donk (2009), the variability in food manufacturing is increased due to an increase of product mix as mentioned in section 2.3.2. Product mix is an issue as different processing time, setup time and routings can vary from product to product. This can potential increase the lead time and operational cost. Even if products have similar processing time, changeover and routing, then this can lead towards the variability induced due to wrong ingredients and not following the SOP (section 6.5)

  As mentioned by Akkerman and Van Donk (2009), the correlation can exist between item types and between package types and can be both positive and negative.

- *Variable machine setting;* as mentioned in section 2.3.2 variable machine setting may increase variability in food production system. For example, in biscuit production line variable machine temperature may affect with the quality of products. For instance, lower oven temperature may increase uncooked products. On the other hand, higher oven temperature may increase burn products.

- *Demand uncertainty;* according to Das and Abdel-Malek (2003), managers should plan to comply with the variability due to the process and product variations. Germain et al. (2008) mentioned that uncertain demand means a highly variable and less streamlined production process. According to Fransoo and Wouters (2000), weather change may be the cause of fluctuation of demand in food products, such as biscuits, people tend to order more biscuits when the weather getting cold as mentioned in section 2.3.3 that weather changes may affect customer demand.

- *Machine breakdowns;* breakdown can be divided into:
  - Short stoppages; i.e. short breakdown. For example , packing machine stopped to top up packing film
  - Long stoppage; i.e. long breakdown. For example, cooling conveyor stopped working biscuit packing.

In addition, according to Van Wezel et al.(2006), machine breakdowns interrupt the production process and may affect the scheduling adherence and capacity planning. Following Van der Vorst et al. (2000), machine breakdowns are one of the daily problems that usually happen in the food industry production lines. The research considers machine breakdown as one of the factors that affect the increasing variability level in biscuit production lines.

- *Changeover*; according to Mclntosh et al. (2002), is change the setting and tools when the production line change producing from one product to another. There are many causes of variability in changeover:
  - Uncertain demand; the demand might change due to weather change.
  - Additional customer orders; the customer may add additional order that need to be delivered in a short time.

    - Last minute orders/Customer priority orders;
    - Product Mix;

- *Uncertain Due Date;* Corti et al. (2006) claims that due date is an estimation of the manufacturing process along the production line from the point of receiving the raw materials from the suppliers to the dispatch point. For example machine breakdown may delay the production and that affect with the due date of raw material and may influence with the final products due date. In addition, the due date of working process material may influence final products. For example, if we produce cream sandwich biscuits, the due date of the final products depend on the due date of the cream. Due date uncertainty can be caused by a number of reasons such as high levels of product mix, machines breakdowns, poor scheduling, lack of raw material (Kang et. al 2014 and Kang et. al, 2015). According to Zorzini et al. (2008), the due date issue may be considered as internal or external as follows:
    - Internal; Zorzini et al. (2008) states that due dates are set within the production planning activity and can thus be controlled within the planning and finite scheduling capacity i.e. relies on the available capacity. For instance, use of optimal job sequence and buffer size to accommodate the high level of variability due to product mix and process variations i.e. by knowing the lead time based on the capacity constrained resource due dates can be set internally (Kang, 2012).
    - *External;* according to Zorzini et al.(2008), it is the flow of information from the point of receiving a customer order, to the factory MRP (Material

Requirements Planning), then to the supplier. For example, due to demand fluctuation (Section 2.3.3) such as weather, promotion events, etc. customer may require delivery date to be adjusted to fulfil the customer demand. Therefore, due dates may be adjusted based on the customer priority (Kang et. al, 2014).

Thus, the research will address different types of variability in biscuit production line such as machine breakdown and variable machine setting.

2.11 Conclusion

Thus, from the above, the research highlighted types and generic characteristics of food production system in order to identify different types of variability. In addition, the research highlighted MTS-MTO as common strategies in food production system and stated their applications in biscuit production line. Some of the variability identified for food production system such as machine breakdown and variable machine setting. The research compares them with the observation of biscuit production line in method steps section 6.5. In the next chapter, the research will state lean and lean principles and the opportunities for implementing lean in food by identifying which principles and tools can be implemented for improving food production system.

Chapter 3: Lean in food

3.1 Introduction

Chapter 2 illustrates different levels of variability and highlighted some opportunities for implementing Lean within MTS-MTO in food production system, in this chapter the research will highlight Lean principles and will investigate which one is most applicable to improve food production system within MTS-MTO environment. Then, section 3.4 categories seven types of waste in food production system and exemplifies the waste with respect to the selected cases study. Process mapping is further used to map the biscuit production process to understand the process and identify added and non-added value activities, section 6.2 provides detailed information about the biscuit production line.

3.2 Lean

According to Womack and Jones (2003), lean had been introduced as a common Japanese approach that caused automotive Japanese companies such as Toyota to lead the market. It mainly focuses in increasing efficiency and reducing waste.

Womack and Jones (2003) define lean as

> *providing the way to specify value, line up value –creating actions in the best sequence, conduct these Activity without interruption whenever someone requests them, and perform them more and more effectively*.

Furthermore, Taj (2008) mentions that lean is the philosophy for improving the different procedures in order to increase production efficiency whereas Melton (2005) defines lean as tools and techniques that help to '*banish'* waste and generate wealth.

According to Dickson et al. (2009), lean thinking is

> *a set of principles and techniques that drive organisations to continually add value to the product they deliver by enhancing process steps that are necessary, relevant and valuable while eliminating those that fail to add value*".

whereas

> *lean production is an integrated set of Activity designed to achieve high-volume production using minimal inventories of raw materials, work-in-process, and finished goods*".
>
> Demeter and Matyusz (2010)

Lean can be adapted in food production system, for reducing cost and increasing customer value (Zarei et al. 2011). Customer value means to "*understand specific requirements for specific end-customers*" (Simons and Zokaei 2005).

From the above, the research can identify lean in food as a set of principles and techniques that specify value and banish waste in order to increase efficiency in food production system.

Thus, the research will apply lean for understanding the process that helps to map it to identify value and none-value activities and understand the process. In addition, the research will categorize seven types of wastes in food waste.

3.3 Lean Principles

There are five main Lean principles (originally defined by Taiichi Ohno) as identified by Womack and Jones (2003) and Bicheno (2000) as follows:

- *Specify value*; Bicheno (2000) stated that the value should mainly concentrate on customer's order fulfilment by providing what the customer needs i.e. understanding the specific customer requirement. According to Womack and Jones (2003), value is defined by customer and is created by the manufacturer. However, as mentioned in section 2.3.2 in the food industry, customer demands might change and introduce the variability in the process, which may affect the value i.e. process may not be able to deliver according to current customer demand. . For instance, when the oven temperature higher than the standard, then the line may produce darker biscuits and that out of customer requirement.

- *Identify Value stream*; according to Womack and Jones (2003), value stream identifies the set of all actions that are required to bring a product to a customer. The research maps a biscuit production line (section 6.2) in order to ide***n***tify value and non-value added activity and help to solve the problem that may cause increases of waste.

- *Flow;* flow "recognises process so products move smoothly through the value creating steps" (Staats et al. 2001). Flow keeps the process running smoothly with minimum waste (Bicheno 2000). In food processing, it's important to insure smooth flow of process by reducing the different types of variability. How this is used in this research (link to appropriate section in chapter 6).

- *Pull;* this means that products are produced based on customer demand (Womack and Jones 2003). In addition, "*pull involves each customer calling output from the previous step*" (Staats et al. 2011).

Pull is also said to reduce waiting time, waste, and stock (Bicheno 2000). Thus, pull can help in reducing the inventory level in MTO environment by producing based on customer demand (section 2.5). In addition, pull can help in reducing work in process in MTS environment (section 2.6).

- *Perfection;* according to Bicheno (2000), Perfection means "*producing exactly what customer wants*", without delay, at reasonable cost, and minimum waste. In addition, perfection is not just quality assurance; it is the processing and delivery of the food product to be made available in high quality. As Staats et al. (2011) mentioned that Perfection needs consistent striving to achieve customer demands and improvement of the process by reducing waste. Thus, Perfection can be implemented in food production system within MTS-MTO in order to achieve customer fulfilment. The research will identify different types of variability in biscuit production line (section 6.5) and then apply improvement in high variable areas (section 6.8). That may reduce waste of time and material.

*Thus from a*bove, the research identified lean principles th*at can be applied in food production system. In* the next section, the research will highlight seven types of waste and categories seven types of waste in biscuit production lines.

3.4 Waste in food

In this section the research will identify seven types of waste in lean and then categories seven types of waste in biscuit production lines.

According to Taj (2005), waste is "*anything other than minimum amount of equipment, materials, parts, and working times that are absolutely essential to production*". Lean categories the process waste into seven types; over processing, waiting time, defective product, level of inventory, transportation, motion , over production , and defects. Table 3.1 explains each type of waste with providing an example from a biscuit production line.

Table 3.1 Types of waste in lean and a case study of biscuit production (Melton, 2005), Research)

7 Types of Waste	Waste in lean	Waste in biscuit production
Over-processing	When the process takes more time than expected.	When packing machine taking longer time than the standard time due to variable temperature.
Waiting time	When the process is idle and waiting for work items. The causes of waiting time can be • Raw material • Flow of material • Breakdown	For instance, If cooling conveyor speed lower than the standard that would increase waiting in packing.
Level of inventory	The storage of items or raw materials that would cost money (Melton 2005).	For instance, in producing cream filled biscuits, if the cream is more than a product need. Thus, more cream biscuits produced more than demand. Therefore, resulted in excessive FGI.
Transportation	According to Melton (2005) this is moving unprocessed product from place to place which is not adding value to the customer.	Moving materials and semi-finished products that are not adding value to the customer. For example, moving recycled biscuits from grinding to mixing.

Motion	Non standardisations reflect in more motion that does not add-value.	If there are no Standard Operating Procedure (SOP) and work instructions for packaging biscuits, then that would result in an extra working motion.
Over production	Melton (2005) mentioned that this is producing more than demand.	When the demand is 300 packets of biscuit and the line produced 350 packets. This is considered waste in time and materials.
Defects	This is an error occurring during the process and requires either rework or must be considered as scrap (Melton 2005).	This is a major problem in food as some products can be recycled or reworked so any mistakes in the process can lead to items being scrapped. For instance, setting the packing machine to the wrong dimensions.

Out of seven Lean waste identified in Table 3.1, current research will use the over processing, waiting time and defects in the case study for the validation process. The waste categories addressed in current research are discussed in more detail in Section 6.5.

3.5 Conclusion

Thus, the research identified opportunities for adopting lean in food by stating lean principles. In addition, the research started with categorising seven types of waste in biscuit production lines.

However, lean is not the only approach that can be applied to reduce variability in food; there are other approaches used for dealing with food variability. Thus, in the next chapter, the research will highlight the existing approaches dealing with variability in food production system, in order to identify the best approach applicable for reducing variability in biscuit production lines.

Chapter 4: Existing approaches to dealing with variability in the food flow processing system

4.1 Introduction

In this chapter, the researcher will critically review the existing approach to deal with variability and compare it with the literature review on different types of variability in food production system (section 2.5). Researchers have used numerous approaches to deal with variability in food production system, such as a mixed integer programme, simulation-based approaches, evolutionary algorithms, rule-based system, etc. This chapter aims to identify an approach that could identify and reduce the mixed levels of variability among different workstations in food production system.

4.2 Full Factorial Design

According to Minitab, *'a full factorial design is a design in which researchers measure responses at all combinations of the factor levels'* (2015). In addition, Minitab offers two types of full factorial design: two levels and more than two levels. For instance, a two-level full factorial design with six factors (2^6) requires 64 runs.

A full factorial design is widely used to understand a system behaviour or problem under investigation by running detailed experiments combining all factor values. For instance, Javorsky et al. (2013) used a full factorial approach to investigate factors such as bonding temperature, humidity, application process and surface primers. The results showed that bonding temperature is most effective with an increasing number of failures. Also, it was observed that the standard temperature is 49C$^{\circ}$.

A full factorial design allows a detailed investigation by observing the system behaviour based on a combination of all factors and their levels. Thus, as the number of factors and the levels increase, full factorial requires a higher number of runs to identify the factor/s affecting the system the most. Thus, applying full factorial may not be ideal for all problems, e.g. for biscuit production line there are 6 factors and 3 levels, which will produce 27 number of experiments. Hence, using full factorial will give the best solution but requires a significant amount of time to run all experiments, which is not acceptable in real world.

4.3 Design of Experiment Taguchi Orthogonal Array (DoE)

According to Khaw et al. (1995), the Taguchi orthogonal array is a mathematical tool designed to reduce the number of experiments required. The Taguchi method generates a set of experiments using the underlined concept of paired comparison. However, the constraint is that no pair is repeated.

According to Radharamanan and Ansuj (2000), the Taguchi method measures variability around a target key performance indicator by studying various types of signal-to-noise ratios, which would reduce the time and effort required to investigate the systems under study (Khaw et al. 1995).

Pereira and Aspinwall (1992) applied the Taguchi OA to biscuit processing to evaluate tolerance and critical parameters in the process design and product manufacturing. The aim of this method is to define and help identify the causes of variability. This method was applied to investigate quality issues as a result of variable biscuit lengths, mainly because of increasing moisture, dimension, and weight. Six factors were investigated: flour type, fat weight, flour weight, water level, mixing time and rest in mixer. The outcome was a significant reduction in biscuit length variability.

The Taguchi orthogonal array, however, only addressed product quality. As mentioned in section 3.4, seven types of waste may affect process variability in food.

Jafari et al. (2008) integrated the simulation model with the L16 Taguchi orthogonal array at four levels and ran 16 simulations with different combinations of factors in order to observe interactions and the main effects.

Thus, Taguchi OA is a useful approach for reducing number of experiments and that help in save time and cost in food production system.

4.4 Mixed Integer Linear Programme (MILP)

Ierapetritou and Floudas (1998) developed a formulation that performs inventory mass balance by applying individual continuous time grids that allow the process event to take place at any time with different task durations. Moreover, they stated that MILP has been implemented successfully in real case studies to control machine breakdown and labour change. According to Ierapetritou and Floudas (1998), the MILP framework depends on the following abstractions:

- Represent the problem by offering each task a process that could give the task sequence at any utilised resource item.
- Use a unique set of binary variables to explain the proceeding task sequence for a uniform handling of discrete resources.

Doganis and Sarimveis (2007) applied the MILP model to production problems and synchronised lot sizing in yogurt production lines in Greece. Their plan was to improve the product and the process sequence and manage the inventory level, as required. The variables can be divided into two types:

Continuous variables:

- Product quantity.
- Utilisation.
- Inventory level.

Binary variables:

- For all products indicating production on a particular day.
- For each possible transition for each changeover, whether it is taking place or not.

In addition, Kopanos et al. (2010) applied a mixed integer programme (MILP) for yogurt lot-sizing problems of product families in the packing stage. The factory has four packing machines and one fruit mixer. The MILP was applied to improve yogurt capacity. The limitation of the facility allows the production of only one particular flavour yogurt at a given production run. The target was to increase yogurt packing capacity by investing in a new fruit mixer that could improve production line capacity. After the fruit mixer was added, the MILP showed a 7.6% improvement, and the inventory cost was reduced by 12.2%. The improvement method focused on adding facilities to increase flexibility and reduce costs. However, other factors such as machine breakdown may need to be considered.

Although the MILP algorithm applied for improving utilisation and adding facilities, this thesis states that the research goal similar: reducing the cost of production and increasing machine utilisation. However, other production problems such as machine breakdown, variable speed, and temperature need to be resolved in order to increase machine utilisation (section 2.10).

4.5 Discrete Event Simulation Modelling (DES)

A simulation model is a computer-based model applied to mirror the real process system in order to investigate the problem/process under study and allows testing of improvement initiatives (Huda, A. M. et all, 2002). There are a number of ways to simulate the process under study, including continuous, discrete-event, agent-based simulation, among others. Current research has used discrete-event simulation (DES) to mimic the biscuit production line. In order to mirror the biscuit production line, the DES package SIMUL8 has been used. According to Jacxsens, L. et all (2009)A simulation model can be used to model and analyse the real environment. Evidently, simulation models have been successfully applied in a number of application areas for modelling and analysis.

Arjona et al. (2001) applied the DES approach to model the transportation and harvesting processes at a Mexican sugarcane farm. The model simulates all the processes in the farm, from harvesting to unloading at the mill yard. The model covers problems associated with harvesting (both mechanical and semi-mechanical) and transportation. Recommendations from the results show that harvesting efficiency is increased by reducing machine utilisation.

Higgins and Davies (2005) used a DES modelling approach to represent the harvesting and transportation of sugarcane in Australia. The aim of the modelling is to understand the harvesting system in different regions in order to highlight bottleneck areas. The simulation model concentrates on increasing the utilisation of bins (as the harvester cuts the cane, and the cane fills a bin on wheels held by a tractor) by increasing harvesting time, which would reduce the waiting time for filling the bin with cane so that the bin is fully utilised in the harvesting season. The result shows that harvesting time should be changed from only during daylight hours to 18 hours, from 3:00 a.m. to 9:00 p.m., to maximise machine utilisation during the season.

According to Ardon-Finch et al. (2008), the simulation system is applicable because it is flexible in terms of modelling flow line length and allowing a number of variables to contribute to the overall variability of individual workstations.

According to Saravacos and Kostaropoulos (1996), the process simulation model has been implemented in the food processing system for control and training purposes, especially when new or complex processes are introduced.

According to Robinson et al. (2014), the advantages of simulation modelling are as follows:

- *Reduction in data collection time.* Collecting data will be for a certain time and process according to the modelling element and system complexity.
- *Simple and basic model.* The model is easily understood by non-experts from both the system modelling and the analysis perspective depends on complexity.
- *Ease of building the model and making changes.* The programme allows you to duplicate model components and then change the modelling elements.
- *Development of a dynamic process map*. This refers to the map of the system under investigation, as well as the discussion of possible changes to the system.
- *Evaluation of improvement ideas.* DES allows the running of different experiments, which means that an idea can be tested prior to implementation.

Data generated through the validation process can be used to convince the management to support changes.

- *Facilitation of discussion.* Franco and Montibeller (2010) mentioned that can facilitate generic discussion around lean practices.

Thus , from above the research found DES is a useful tool that can be applied in food production system for running the experiments and that can save time, efforts , and materials.

4.6 PolyAnalyst

According to Schikora and Godfrey (2003), PolyAnalyst is a data mining package that has advanced knowledge discovery algorithms that help analysts simplify knowledge from a database to allow them to reduce variability and predict future situations.

In addition, Gürbüz (2010) explained that the following are some of PolyAnalyst's prediction examination tools:

- *Linear regression.* According to Gürbüz, *'it is the process of creating a line through a space such that the sum of the squares of the distance between the line and each point is minimised'* (2010)*. Regression can be a*pplied with any numbe*r of elements, and then it automatically decides which elements provide the best linear prediction rule. However, the linear regression tool can only* predi*ct* linear models, as it is poor at predicting any nonlinear models.
- *Find Laws.* According to Schikora and Godfrey (2003), Find Laws used PolyAnalyst's Symbolic Knowledge Acquisition Technology (SKAT). In addition, in searching for hidden useful dependencies in data expressing the exposed knowledge clearly in the representative structure as a mathematical

formula, that including relational operators, conditional blocks, and rational polynomials. However, Find Laws may take a long time to run.

- *PolyNet Predictor.* According to Gürbüz (2010), this is a PolyAnalyst neural network tool. It creates a network of nodes, each one containing a mathematical expression that can be used to predict the value of an element based on the value of several others. Thus, for a small amount of data, the result can be displayed as a symbolic rule. For large amounts of data, on the other hand, the tool operates like a 'black box'. Then, the data pass through the network in order to get a valid prediction. Among PolyAnalyst tools, PolyNet is the one that can deal with the large number of records.

Therefore, from above, linier regression can only deal with liner models only. However, the research will not use linier model. In addition, find laws may take long time. However, the research requires approaches that reduce number of experiments using Taguchi OA. Although, predictor can be used to predict the value of element, combination of simulation model and rule-based allow validate the improvement before applied in the real production line.

4.7 Rule-Based Approach

The rule-based approach is one of the artificial intelligence approaches that can be used to reduce variability. According to Bagis (2008), the rule-based approach provides quick and proficient solutions to a nonlinear and complex modelling problem. In addition, it can integrate information from different sources that could be used to accurately illustrate system variability.

Iqbal and Dar (2011) mentioned that in order to maintain a high level of production rate and product quality, rule-based modelling is used to predict the value of performance measures in different manufacturing processes.

Iqbal and Dar (2011) used a fuzzy-rule-based approach on a steel cutting machine. They considered three variables: supply rates, strength of cut and cutting speed and response variable such as surface roughness. The implementation of the fuzzy-rule-based system showed an improvement in cutting performance.

Castro and Camargo (2004) stated that the rule-based system is a fuzzy system that applies a basic methodology in dealing with process variability. In addition, it is widely applied to model and control problems. Thus, based on the aforementioned statements, this research may define the rule-based approach as an artificial intelligence tool that can provide quick and efficient solutions to reducing variability in food production system. Thus, from above, the research found rule-based system is a useful approach that can be applied to improve high variable areas in food production system.

4.8 Conclusion

The research has found existing approaches to dealing with variability in food production systems. However, some approaches to dealing with scheduling, such as MILP, are out of the scope of this research. PolyAnalyst only deals with linear and large amounts of data and takes a long time to run. However, the research require quick response approach can be applied in food production system. Full factorial requires a larger number of experiments compared with the Taguchi OA.

Therefore, the research found some useful approach can be used for identifying different types of variability and reducing them in food production system. DES can be considered to mirror the real production line (section 6.6). In addition, Taguchi OA can be applied for reducing number of experiments. For process improvement, the research may consider rule based approach based on SOP as the improvement can be applied in high variable areas (section6.9).

Integrating approaches is helpful for reduce time, effort, and materials. For instance, integrating of DES and DoE can be applied to run different scenarios in order to identify the highest effected KPI (section 6.7). . In addition, the improvement can be validated by integrating DES and rule-base approach (section 6.9).

In the next chapters, this research will highlight the research methodology and identify applicable methods for this thesis. In addition, it will explain the methodological steps of the proposed integrated approaches to reduce variability in food flow processing systems.

Chapter 5: Research Methodology

5.1 Introduction

After this research highlighted existing approaches and defined the proposed approach for reducing variability in a food flow processing system, it will state the method used in this thesis.

Research methods can be divided into two: qualitative and quantitative. This research will use qualitative and quantitative methods because collecting data requires semi-structured interviews to validate the data and define the cause of the problems. In addition, the literature review needs to state the existing approaches used for reducing variability in food production system. Then, a quantitative method will be applied to formulate the experiment.

5.2 Qualitative Method

Preece (1994) noted that a qualitative method is used for assigning a qualitative data that is mainly based on a survey, or case study, such as a literature review or a fact explanation. In addition, according to Hancock (1998), a qualitative methodology can be considered an operational study that uses intensive analysis of the collected data.

Creswell (2003) defines a qualitative approach as *'one in which the inquirer often makes knowledge claims based primarily on constructivist perspectives'*.

This research will thus highlight some qualitative methods and identify which method can be used in this thesis.

5.2.1 Literature Review

According to Ridley (2008), a literature review is *a selection of available documents (both published and unpublished) on the topic, which contain information, ideas, data and evidence written from a particular standpoint to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed*.

In addition, a literature review has several features that could improve a research. According to Kumar (2005), a literature review is one of the research methodologies that have a number of features:

- It has an academic background of study.
- It has rectification that purifies the research methodology.
- It provides an opportunity to contribute to current knowledge in the relevant field and the research profession.
- It increases chances of connecting research findings.

This research, thus, will use a literature review to state current research, methods/techniques to solve the problem and identify the novelty.

5.2.2 Case Study

A case study connects assumptions with reality. Jankowicz (2005) mentioned that a case study uses a range of techniques in the workplace setting in order to investigate a concern in the present as well as in the past. Additionally, it can be a single study or a comparative one that characterises different potentials for the organisation concerned and makes a recommendation for their future. The research, therefore, takes a biscuit production line as a case study to represent a food flow processing system (section 6.3).

5.2.3 Qualitative Research Questions

Creswell (2003) explained that qualitative research questions consist of central questions and sub-questions. These questions should be broad and related to a specific qualitative strategy examination. However, this research will not use research questions as the aims and objectives of this study have already been defined.

5.2.4 Interview

According to McNamara (1999), the interview is a useful tool for obtaining required information from applicants. In addition Interview is time consuming and it is resource

intensive (Kvale, 1996). Beatham (2003) has identified three types of interview:

- Structured interview, Thus uses firmly structured questions with the main of presenting the questions in a same manner for each interview.
- Semi-structured interview, mainly based on open-ended questions to obtain more knowledge about process/system or to externalise the tacit knowledge about a problem domain.
- Unstructured interview, which uses unintended discussions about the subject.

This research used a semi-structured interview for data collection and validation of the model parameters and results for asking the root causes of the problem:

- What was the problem?
- How frequently did it happen?
- What was the cause of the problem?
- How long did it take to address the problem?

5.2.5 Observations

According to Creswell (2003), observation includes field notes on the performance and behaviour of individuals at the research site. The research collected data through observations of the process output of the biscuit production line and machine downtime.

Based on the observations and the semi-structured interviews (Appendix A), the research will identify the types of variability in the biscuit production line (Section 2.10). It will use a combination of qualitative and quantitative methods.

5.3 Quantitative Method

According to Preece (1994) a quantitative method is used to measure or show quantity, such as in a statistical analysis. In addition, Adetunji (2005) mentioned that a quantitative methodology is used in the social sciences to gather a large amount of data and to analyse these data statistically or mathematically.

Creswell (2003) defines a quantitative approach as *'one in which the investigator primarily uses post positivist claims for developing knowledge, i.e. reduction of specific variables'*. The research will discuss studies that use a qualitative methodology in order to identify which approach is applicable for this thesis.

5.3.1 Quantitative Research Questions (Questionnaire)

Creswell (2003) mentioned that quantitative research questions are usually used for shaping and specifying the purpose of the study. Research questions are enquiring statements or answer-seeking questions.

According to Kumar (2005), a questionnaire contains a list of questions given to respondents. Questionnaires are normally used in the social sciences, especially in survey studies. This research, therefore, will not use questionnaire observations to collect data.

5.3.2 Surveys

According to Graziano and Raulin, a survey is used to *'gather information by specifically asking participants about their experiences, attitudes, or knowledge'* (2004).

Creswell, on the other hand, mentioned that *'a survey design provides a quantitative or numeric description of trends, or opinions of a population by studying a sample of that population'* (2003).

This research will therefore not consider questionnaire observations in collecting data.

5.3.3 Experiment

Experiment is one of the research methods that can be used to test the approach used in this study. According to Preece (1994), experiment is anything done to examine an idea or assumption or to determine something unknown.

This research has used an experimental approach, where different set of experiments are developed using Taguchi OA approach in order to investigate the effect of variability on selected performance measures (Section 6.7). This has helped to develop the rules for improving the food production system process (Section 6.9). Section 7.2 illustrates the experimental results in more detail. The main advantage of using an experimental approach is that different scenarios can be investigated to determine the effect of variability on the food processing system.

5.4 Conclusion

This research will apply a combination of qualitative and quantitative methods, as illustrated in Section 5.2 and 5.3. Qualitative methods will include a literature review to highlight current research. The case study uses as an example of a food production system. In addition, semi-structured interviews applied to validate data and identify the cause of the problem. Quantitative methods will include data collection through observation and a formalised research approach using experimentation.

After the qualitative and quantitative methods applicable in this thesis have been identified, the methodological steps used to fulfil the research aim will be explained in the chapter 6.

Chapter 6: Methodological Steps

6.1 Introduction

This chapter discusses the steps undertaken to establish the research methodology. The aim of the research is to reduce the effect of process time variability in the food production system. This aim will be achieved through the following objectives (section1.3):

- To illustrate the types of production so as to facilitate the understanding of the food flow processing system.
- To highlight the generic characteristics of food production system so as to help identify different types of variability in food production system.
- Understanding the effect of variability in MTS-MTO food production system by determining the effect of variability on given KPIs.
- Root cause analysis to identify the main cause of variability.
- Development of an integrated approach to reduce the effect on variability for hybrid MTS-MTO food production systems.
- Development of a process improvement methodology to address the different problems in food production system.
- To identify the higsht effected KPI and define the factors that increasing variability on the effected KPI.
- To apply process improvement to improve the highest variable areas using the artificial intelligence tool, the rule-based system.

This research will use an example of food production system based on the researcher's previous experience. The researcher worked for two years as a process improvement manager at the National Biscuits & Confectionery Company (NBCC) in Saudi Arabia. The factory has over 15 production lines producing more than 60 different types of snacks, including biscuits, wafers, chips and popcorn. The methodology is validated for the biscuit production line, that is, Line 12.

In order to achieve the stated aim, an integrated approach has been proposed using process mapping, discrete-event simulation, Taguchi orthogonal arrays and rule-based systems. There are numerous examples where integrated approaches are used to solve manufacturing problems, and integrated approach will allow:

- Improved process understanding though process mapping.
- Process mapping creates a process flow for identifying value-added and non-value-added activities and will help developing a discrete-event simulation (DES) model.
- A DES model will mimic the real world environment and will allow experimentation in a controlled environment without interrupting the production process.
- Taguchi OA will help to generate the reduced experiment set compared to full factorial approach in order to investigate the effect of variability on the food production system.
- Integrating the DES and DoE will facilitate running different scenarios, which will help in identifying the area and KPIs effected due to process time variability.

- Based on the correlation analysis and SOP process improvement rules will be developed and by integrating these rules with the DES model will allow to understand the effectiveness of proposed solution.

Figure 6.1 shows the research steps.

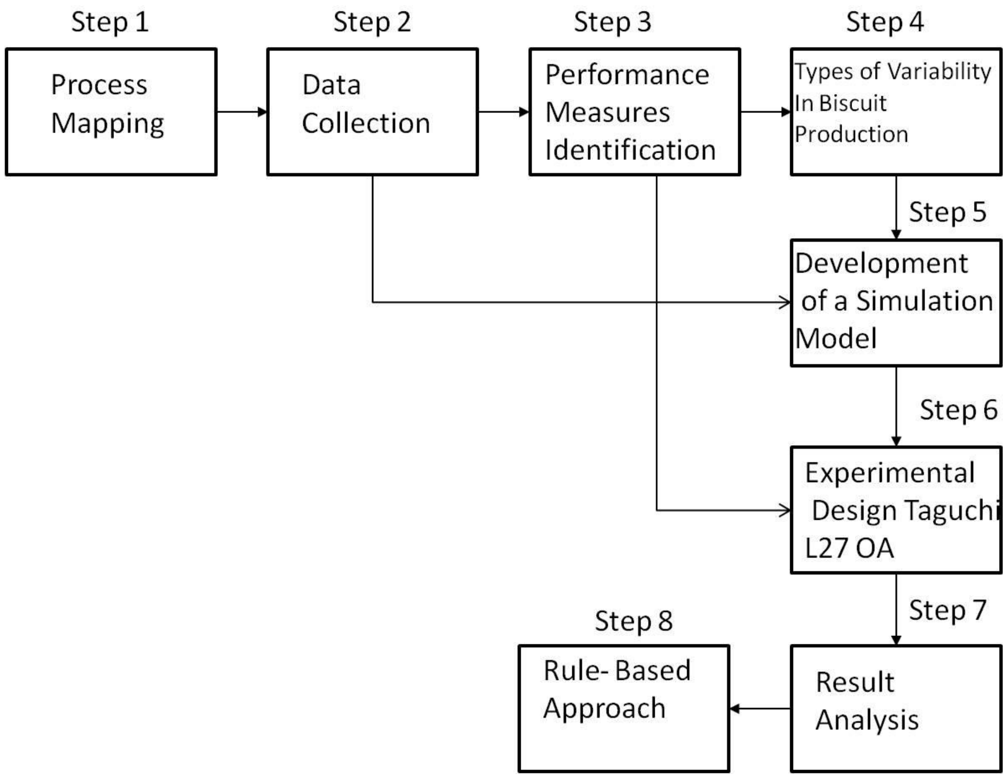


Figure 6.1 Research steps

6.2 Step 1: Process Mapping

Process mapping is one of the lean techniques that provide a visual representation of the sequence of activities that compose a process and can help in identifying value and non-value-added activities in the processing system. According to Greasley (2006), process mapping demonstrates the interrelationships between activities and defines the fundamental tasks in process implementation. Process mapping has been used by many researchers to understand the process and interrelationship between activities and identify non-value-added activities; for example, Kang et al. (2015) applied process mapping for the carbon fibre manufacturing process to understand the interrelationship between different activities. Similar to any other manufacturing process, the food production system consists of a number of sequential activities. In this research, process mapping is used to understand the process flow, associated variables and activities. The tasks on the biscuit production line include the following:

- *Dough mixing:* Mixing involves three stages, starting from combining chemical leaveners with water and then adding flour and sugar and mixing them using a dough mixing machine.
- *Dough cutting:* Cut dough into pieces to feed the next process.
- *Dough laminating:* Laminate dough, through three pressing stages, into sheet to be ready for cutting.
- *Cutting:* Cut dough sheet into biscuit shapes using roller cutter.
- *Baking:* Bake dough pieces in tunnel oven.
- *Cooling:* Cool baked biscuits through cooling conveyor.
- *Aligning:* Align biscuits in penny stack conveyor to be ready for packing.
- *Packing:* Pack stack of biscuits using packing films.
- *Packaging:* Pack the packets into cartons.
- *Biscuit recycling/grinding*: Recycle rejected biscuits using a grinding machine and add them into the mixer.

Figure 6.2 shows the process map for the biscuit production line, Line 12. Following this, the research will collect data from the biscuit production line. Detailed process information is provided in Appendix B and C.

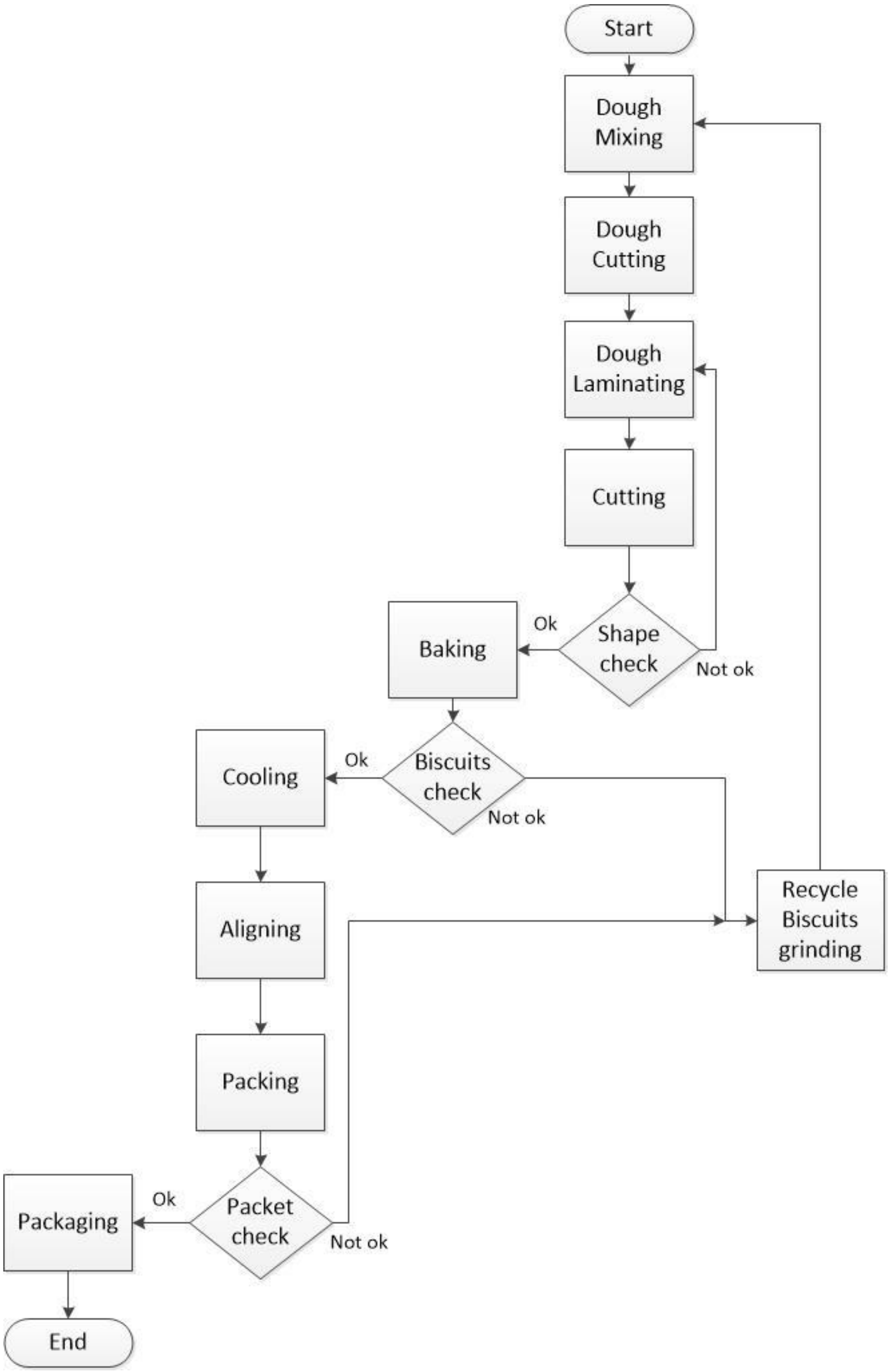


Figure 6.2 Line 12 process mapping

6.3 Step 2: Data Collection

Data are collected from the biscuit production line of NBCC, Line 12, which is based in Saudi Arabia.

It was a new line under commission with high variability. Table 6.1 and 6.2 show a snapshot of data collected from Line 12. From Tables 6.1 and 6.2, it can be seen that data related to material waste was collected every three hours. For example in this case, Table 6.1; Oven produces a lots of wastes, materials wastes was collected every three hours i.e. 380 kg from 8:30 am to 11:30 am was, and the total wastes was 446 kg with 41% of total wastes because of bad appearance biscuits that took 22 min 20 sec.

Appendix A contains data collected from Line 12 for research purposes. The observations include measuring waste in the production line to establish improvement needs and identifying the main causes of waste through semi-structured interviews with operators. Data were collected for five months.

Table 6.1 Example of data collection

Line 12 Waste (kg) Commissioning 7/2/06												
Process	Activities	Time								Total	Waste %	Comment
		8:30–11:30 a.m.	11:30–1:00 p.m.	1:00–3:00 p.m.	3:00–6:00 p.m.	7:00-10:00 p.m.	10:00–1:00 p.m.	1:00–3:00 a.m.	3:00–6:00 a.m.			
Mixing	Magnetic Detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	5.00	3.00	2.00	4.00	3.00	20.00	1.85	
	Press 1	3.00	2.00	2.00	3.00	3.00	5.00	5.00	1.00	24.00	2.22	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	380	20.00	10.00	5.00	2.00	3.00	25.00	1.00	446.00	41.22	Bad appearance 22 min 20 sec
Cooling	Slide	2	0.00	0.00	0.00	0.00	0.00	0.00	0.50	2.50	0.23	
	Bypass	70.00	0.00	0.00	25.00	35.00	96.00	5.00	65.00	296.00	27.35	Cavana 2 sealing problem in shift B 24 min 30 sec
	Penny st. Guids1	0.10	0.20	0.10	0.00	0.20	0.30	0.00	0.00	0.90	0.08	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.10	1.00	0.00	0.00	1.10	0.10	
Aligning	Vibrator 1	0.50	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.70	0.06	
	Vibrator 2	0.40	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.70	0.06	
	Guide Bars Chine1	15.00	0.00	1.00	3.00	4.00	1.00	1.00	1.00	26.00	2.40	
	Guide Bars Chine2	15.00	0.00	2.00	4.00	5.00	1.00	9.00	1.00	37.00	3.42	
	Guide Conveyer1	0	0.10	0.00	0.00	0.00	2.00	0.40	0.00	2.50	0.23	
	Guide Conveyer2	0	0.10	0.00	0.00	0.00	0.00	0.50	0.00	0.60	0.06	

Packing 1	Cavana 1	0.50	4.00	15.00	0.00	10.00	35.00	5.00	0.10	69.60	6.43	
Packing 2	Cavana 2	0.50	0.00	13.00	0.00	8.00	35.00	4.00	35.00	95.50	8.83	Sealing problem in shift B 25 min 40 sec
Packaging 1	End seal 1	10.00	3.00	4.00	0.00	10.00	4.00	1.00	0.00	32.00	2.96	
Packaging 2	End seal 2	7.00	4.00	2.00	0.00	10.00	3.00	1.00	0.00	27.00	2.50	
Total waste		505.00	34.40	50.10	45.00	90.50	188.60	60.90	107.60	1082.10		
Accept Products		2776.8	3310.80	2776.80	2883.60	3268.10	3449.64	3449.64	2178.72	24094.10		
Total		3281.80	3345.20	2826.90	2928.60	3358.60	3638.24	3510.54	2286.32	25176.20		
Line Efficiency %		84.6	99.0	98.2	98.5	97.3	94.8	98.3	95.3	95.7		
Waste %		15.4	1.0	1.8	1.5	2.7	5.2	1.7	4.7	4.3		
Total Process Waste = 490, 45.3% of waste												
Total Packing Waste = 592.1, 54.7% of waste												

Table 6.2 Example of a data collection

Line 12 Waste (kg) Commissioning 15/2/06												
		Time										
Process	Activity	7:00–11:15 a.m.	11:55–1:00 p.m.	1:00–3:00 p.m.	3:00–6:00 p.m.	7:00–10:00 p.m.	10:00–1:00 p.m.	1:00–3:00 a.m.	3:00–6:00 a.m.	Total Wastes Kg	Waste %	Comment
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	4.00	1.00	2.00	1.00	4.00	15.00	0.73	
	Press 1	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	6.00	0.29	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	3	45.00	30.00	43.00	15.00	6.00	3.00	11.00	156.00	7.55	Bad appearance 20 min 30 sec
Cooling	Slide	1	0.00	1.00	0.00	2.00	0.00	0.00	0.00	4.00	0.19	
	By-Pass	40.00	80.00	30.00	50.00	125.00	150.00	50.00	150.00	675.00	32.67	Waiting due to breakdown in packing 1 Shift A 15 min 20 sec
	Penny st. Guids1	2.00	0.00	1.00	0.00	2.00	0.00	0.00	0.00	5.00	0.24	
	Penny st. Guids2	2.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	4.00	0.19	
Aligning	Vibrator 1	0.00	4.00	0.00	0.00	1.00	0.00	0.00	0.00	5.00	0.24	
	Vibrator 2	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.29	
	Guide Bars Chine1	3.00	10.00	2.00	5.00	15.00	15.00	10.00	0.00	60.00	2.90	
	Guide Bars Chine2	4.00	25.00	10.00	8.00	15.00	15.00	10.00	0.00	87.00	4.21	
	Guide Conveyer1	0.1	2.00	1.00	0.00	15.00	15.00	25.00	10.00	68.10	3.30	
	Guide Conveyer2	8	15.00	5.00	0.00	10.00	15.00	0.00	25.00	78.00	3.78	
Packing 1	Cavana 1	15.00	50.00	20.00	2.00	50.00	50.00	50.00	25.00	262.00	12.68	Programme hang 10 min\Broken biscuit (Loader Problem) 25 min 10 sec
Packing 2	Cavana 2	45.00	60.00	30.00	35.00	50.00	50.00	55.00	25.00	350.00	16.94	Broken biscuit (Loader Problem) 20 min 40 sec
Packaging 1	End seal 1	10.00	20.00	10.00	8.00	50.00	0.00	0.00	10.00	108.00	5.23	
Packaging 2	End seal 2	20.00	50.00	20.00	22.00	50.00	0.00	0.00	15.00	177.00	8.57	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total Waste Kg		155.10	368.00	163.00	177.00	403.00	319.00	205.00	276.00	2066.10	Total Process Waste = 132 kg ,18.7% of Total Waste	

Accept Products	2400.0	2148.0	2496.0	3036.0	3468.0	3468.0	2912.0	2912.0	22840.0	Total Packing Waste = 573 kg ,81.3% of Total Waste
Total	2555.10	2516.00	2659.00	3213.00	3871.00	3787.00	3117.00	3188.00	24906.10	Dough Waste = 2.7% of Total Waste
Line Efficiency %	93.9	85.4	93.9	94.5	89.6	91.6	93.4	91.3	91.7	Biscuit Waste = 39.86% of Total Waste
Waste %	6.1	14.6	6.1	5.5	10.4	8.4	6.6	8.7	8.3	Biscuit with Wrapper Waste = 57.45% of Total Waste

6.4 Step 3: Identify Key Performance Indicators (KPIs)

The KPIs play a key role in addressing organisational problems and identifying performance gaps by providing a system to collect measures and compare them (Taj, 2008). In current research, KPIs are used to quantify system performance based on selected measures. The KPIs are selected based on data collection of process time variability (Appendix A) and that indicate waste of time with the root causes which reflect wastes of materials, breakdown, and throughput reduction. The KPIs that need to be improved are the following:

- % Stopped
- % Blocked
- % Waiting

System performance measurements that need to be increased are the following:

- % Working
- Throughput

Figure 6.3 shows the overall objective of the selected performance measures.

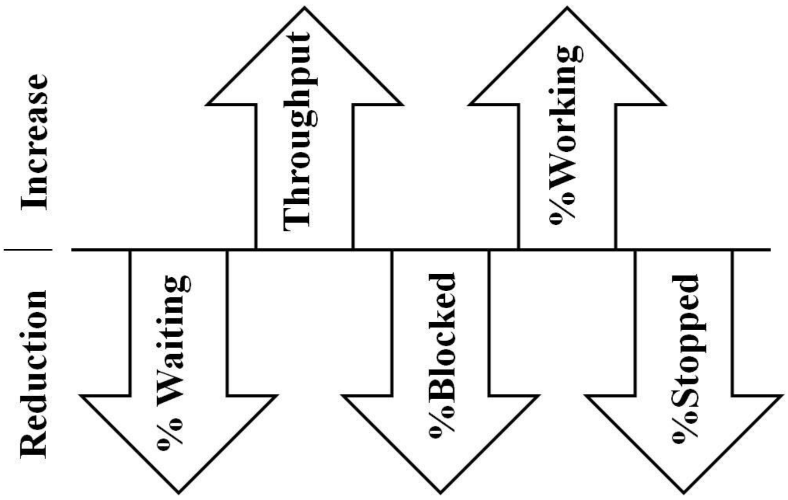


Figure 6.3 Overall objective of the selected KPIs

6.5 Step 4: Types of Variability in a Biscuit Production Line

The types of variability in a food production system have been identified based on the data collected and observations made in a span of five months (Table 6.1 and Appendix A), as well as on manufacturing standards such as standard operating procedures (SOP) (Appendix B), work instructions (Appendix C) and product parameters (Appendix D). Table 6.3 summarises the different types of variability in a biscuit production line.

In this research, triangular distribution is used to represent the different levels of variability. Triangular distribution is used as it provides an acceptable trade-off between the accuracy of results and estimation of distribution parameters.

- MTTR (mean time to repair) – average time to resolve the problem when it happens.
- MTTF (mean time to failure) – average time between failures, that is, between problem occurrences.

Thus, different types of variability associated with work centres in a biscuit production line are shown in Table 6.3. Table 6.3 includes the modelling element (Line 12 work centre or activity), standard processing time for each modelling element, attributes, value and a detailed variability description. Standard process times are represented by a triangular distribution, that is minimum, average, and maximum time. The research described attributes for each area, including mean time to repair and mean time to failure for different types of variability. In addition, different types of variability stated a cause and standard operating procedure (SOP). Information in Table 6.3 is used to derive the experiments (Table 6.6).

Table 6.3 Variability description

Modelling element	Processing time (Mins)	Attributes	Values	Variability			
				Type	**Description**	**Cause**	**Manufacturing standard**
Mixing	11, 13, 15	MTTR	5, 10, 15	Mixing wrong ingredients and quantities	Wrong amount of sugar for tea biscuits	Mix of ingredients of similar products	Tea biscuits need to have amount of sugar as 70 kg±0.5
Roller cutter	1, 2, 3	MTTR	5,10, 15	Bad product size	Bad cutting shapes. Tea biscuits width is 39 mm	Wrong setting	Shapes should be as the specifications (e.g., tea biscuits' width is 45 mm±2)
		MTTF	120,140,160				
Baking	15,20, 30	MTTR	10,15, 20	Low temperature	Uncooked biscuits	Heating temp in zone1 = 160°C	Exp. tea biscuits' heating temp in zone 1 = 180°C (+35 or –10)
		MTTF	20,40,80				
		MTTR	20,40,60	High temperature	Burned biscuits	Baking cycle time is 5.15 min	Exp. tea biscuits' baking cycle time is 4.45 min
		MTTF	100,200,300				
		MTTR	15,20, 25	High temperature	Tea biscuits temperature in zone 3 is 260°C	Reset up oven	Tea biscuits' temperature in zone 3 is 188°C (+35 or –10)
		MTTF	200,260,320				

		MTTR	10,25, 40	Moisture	High moisture caused by increasing tea biscuits' weight to 120 gm	Either from ingredient or from variable oven temperature	Tea biscuits' weight is 100 g ±3
		MTTF	30,180,280				
Cooling conveyor	5, 10, 15	MTTR	15,20, 30	Long breakdown	Conveyor stoppages	Suddenly stopped at speed of 0 m/sec	The conveyor should run smoothly at speed of 4m/sec
		MTTF	100,150,300				
		MTTR	10,25, 40	Speed	Cooling conveyor speed is 2.8 m/sec	Conveyor motor breakdown	Cooling conveyor speed should be 4 m/sec
		MTTF	120,200,360				
Aligning	3, 5, 7	MTTR	5,10, 15	Short breakdown	Vibrator not working properly	Not vibrating well enough to align biscuits 1.4 t/m^3	Vibrator should arrange for aligning biscuits for packing 1.6 t/m^3
		MTTF	80,100,120				
		MTTR	15,25, 35	Short breakdown	Sensors not working	Stopped working	Slide sensor for aligning biscuits
		MTTF	200,260,280				

		MTTR	5,8,10	Short breakdown	Out-of-lining biscuits	Wrong slides adjustments	Biscuits aligning for packing
		MTTF	40,60, 80				
		Change over	20,30, 40	Speed	Reduction in aligning speed	Fault in changeover. The slides are not completely changed	When changing from tea biscuits to Taib, the slides should be changed
		MTTR	10,15, 20	Short breakdown	Broken biscuits due to out-of-standardisation size of products causes from cutting or baking	Tea biscuits' dimension is 58 mm x 38 mm x 4.5 mm	Tea biscuits' size 64 mm x 45 mm x 6.35 mm
		MTTF	40,60, 80				
Packing1	0.02,0.03,0.05	MTTR	10,20,40	Short breakdown	Programming faulty in packing machine	Run tea biscuit at 198 packet/min	The packing programme for running tea biscuit 217 packet/min
		MTTF	40,140,280				
		MTTR	20,40, 60	Long breakdown	Exit belt broken in packing machine	Machine breakdown	Exit belt run at speed of 3 m/sec
		MTTF	120,200,280				
		MTTR	25,30,35	Long breakdown	Packing sensor breakdown		Packing sensor should be set up 0.05

		MTTF	120,260,280				
		MTTR	10,15,25	Moisture	High moisture products	Uncooked biscuit	Tea biscuit moisture after packing should be 3%
		MTTF	100,120,130				
Packing 2	0.02,0.03,0.05	MTTR	10,15,20	Short breakdown	Printing wrong code in packing machine	Wrong machine adjustment	Code should be clear and in the correct position
		MTTF	80,100,120				
		MTTR	20,30,40	Long breakdown	Machine stoppage	Machine breakdown due to sensor problem	The machine sensors should work properly
		MTTF	120,140,160				
		MTTR	20,40,60	High temperature	Bad sealing	Sealing temp is 62°C	Tea biscuits' sealing temp is 56°C±3
		MTTF	100,200,300				
Packaging 1	3,5,7	MTTR	10,150,20	Moisture	Decreasing in biscuits' thickness; tea biscuit thickness is 5.5 mm	Biscuit thickness lower than the standard	Tea biscuit's thickness is 6.35 mm ±0.2
		MTTF	240,260,280				
		MTTR	60,120,240	Long breakdown	Exit belt broken in packing machine	The belt runs at speed of 1 m/sec	Exit run at speed of 3 m/sec
		MTTF	300,400,500				

			0				
Packaging 2	3, 5, 7	MTTR	25,30,40	Long breakdown	Cavana finger out of timing	Tea biscuit 15 packet/min	Cavana figures for tea biscuit 20 packet/min
		MTTF	60,80,100				

6.6 Step 5: Discrete Event Simulation Model (DES)

After the implementation of the process map, the research developed a discrete event simulation model for the biscuit production line, that is, Line 12. DES model is developed using simulation package Simul8.

Table 6.4 shows simulation parameters. In addition, table 6.5 shows simulation model inputs, including workstation and process time in the form of triangle distribution obtained from the standard operating procedure (SOP) (Appendix B) and work instruction (Appendix C). Figure 6.5 shows the simulation model.

Table 6.4 Simulation parameters

Simulation parameters	***Value***
Simulation run time	870,000 mins; this was used because it represents 5 months of production.
Travel time	This was set to zero because the products move directly to the next process.
Random time	No randomness is used as model represents the real working area.
Shift pattern	No shift pattern is used because the data collected in the commissioning process are planned in the day shift.

Probability distribution	Triangular distribution that facilitate the level of variability.
Resources	Operators are used to represent the real-life scenario. however, PMs associated with operators are not used for analysis as this is out of the scope of this research.
Routing	Routing is fixed as model is focused on one product, and it follows the same route.
Customer demand	Model is executed for a fixed run time; therefore, customer demand is not used. In other words, Line 12 represents a MTS strategy.

Table 6.5 Modelling elements and associated attributes

Workstation	Process time mins(min, mean, max)	Recycle%	Scrap%
Dough mixing	11,13,15	0	3
Dough cutter	3,5,7	0	2
Laminator	5,7,10	1	0
Roller cutter	1,2,3	1	0
Baking	15,20,30	1	0
Cooling conveyor	5,10,15	3	2
Aligning	3,5,7	5	2
Packing machine 1	2,3,5	5	2
Packing machine 2	2,3,5	8	4
Packaging 1	3,5,7	9	2
Packaging 2	3,5,7	6	2

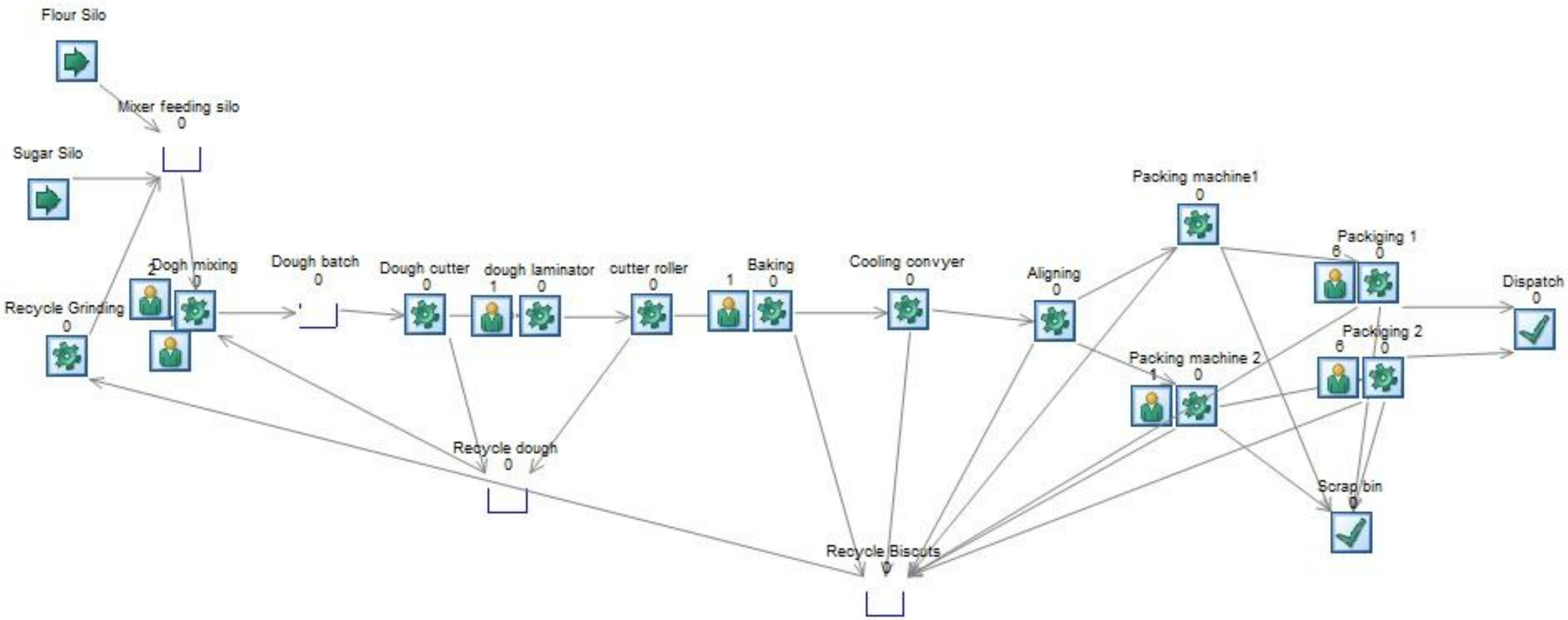


Figure 6.4 Simulation model for the biscuit production line

6.7 Step 6: Taguchi Orthogonal Array

After the simulation model is developed, the research will apply the Taguchi orthogonal array to generate different scenarios in order to investigate the effect of variability and identify improvement opportunities. As described in Chapter 4, the Taguchi OA provides an advantage over the other DoE approaches because it reduces the number of experiments required. The Taguchi OA consists of the following steps:

- Identify the main factors in a biscuit production line.
- Define variability levels.
- Apply modelling position.
- Choose the Taguchi OA.
- Apply design of experiment.
- Run experiments and collect results.

The research will discuss each step:

1. Identify the main factors in the biscuit production line.

The process starts with identifying the suitable Taguchi OA for a given problem based on the number of factors and levels. Therefore, the research needs to identify the main factors causing the variability in the biscuit production line and define their variability levels.

Table 6.6 shows the identification of the main factors (MTTR and MTTF) of a biscuit production line generated from the summary of observations in Table 6.3. For example, Table 6.3 shows uncooked biscuits because of low temperature. Therefore, low temperature is considered as one of the factors in Table 6.6. For low temperature, MTTR value is obtained from 10 to 20 and it is determined based on the duration of the breakdown , MTTF value is obtained from 20 to 80 and it is determined based on time between breakdown .Similarly, MTTR and MTTF values related to other factors are obtained from Table 6.3.

Table 6.6 Main factors of the biscuit production line

Factors	MTTR	MTTF	Workstation
Moisture	10,25,40	30,180,280	Baking
Speed	10,25,40	120,200,360	Cooling conveyor
Low temperature	10,15,20	20,40,80	Baking
High temperature	20,40,60	100,200,300	Baking, packing 2
Short breakdown	10,20,40	40,140,280	Packing 1
Long breakdown	60,120,240	300,400,500	Packaging 1

2. Define the levels of variability.

Table 6.7 defines different levels of variability based on the MTTR and MTTF values identified for the factors in table 6.6. For instance, Moisture, Speed and Temperature (table 6.6) has three levels of variability i.e. low, medium and high. While, breakdowns have only two levels i.e. short and long. The Based on MTTR and MTTF in Table 6.6, there are three levels of variability as shown in Table 6.7: low, medium and high for moisture, speed and temperature. In addition, breakdown has two levels: short and long. For example, moisture in Table 6.6 is represented by MTTR in three levels: minimum 10, medium 25, and maximum 40. Therefore, moisture in Table 6.7 has three levels: low, medium, and high.

Table 6.7 Levels of variability

Variables	Level 1	Level 2	Level 3

Moisture	Low	Medium	High
Speed	Low	Medium	High
Temperature	Low	Medium	High
Breakdown	Short	Long	

3. Apply modelling position.

After defining the applicable array for the case study, the research will apply the modelling position, which will divide the areas into three positions based on the three main areas, namely, mixing, baking and packing, in order to integrate the Taguchi OA into the simulation model. Table 6.8 shows the modelling position for the Taguchi OA, which is divided into three positions.

Each position includes four areas, which will be implemented for the transfer of the Taguchi OA to the design of the experiment. Modelling position chosen based on the main areas of biscuit production line and that facilitate representing production line in Taguchi OA

Table 6.8 **Modelling position**

Position	**Area**	
1	Dough mixing	Dough cutter
	Laminator	Roller cutter
2	Baking	Cooling conveyor
	Aligning	Packing machine 1
3	Packing machine 2	Packaging 1
	Packaging 2	Recycle grinding

4. Choose the Taguchi array.

The model contains levels of triangular distribution, six factors, and three maximum levels as shown in Tables 6.7 and 6.8, respectively. Therefore, the research will apply L27 array as shown in Table 6.9.

Table 6.9 L27 array

Exp	Moisture	Speed	Low temperature	High temperature	Short breakdown	Long breakdown
1	1	1	1	1	1	1
2	1	1	1	1	2	2
3	1	1	1	1	3	3
4	1	2	2	2	1	1
5	1	2	2	2	2	2
6	1	2	2	2	3	3
7	1	3	3	3	1	1
8	1	3	3	3	2	2
9	1	3	3	3	3	3
10	2	1	2	3	1	2
11	2	1	2	3	2	3
12	2	1	2	3	3	1
13	2	2	3	1	1	2
14	2	2	3	1	2	3
15	2	2	3	1	3	1
16	2	3	1	2	1	2
17	2	3	1	2	2	3
18	2	3	1	2	3	1
19	3	1	3	2	1	3
20	3	1	3	2	2	1
21	3	1	3	2	3	2
22	3	2	1	3	1	3
23	3	2	1	3	2	1
24	3	2	1	3	3	2
25	3	3	2	1	1	3
26	3	3	2	1	2	1
27	3	3	2	1	3	2

5. *Apply the design of the experiment.*

After the research defines the array and identifies the modelling position, L27 OA is generated as shown in Table 6.9. Table 6.8 is obtained from Tables 6.6, 6.7 and 6.8. Table 6.9 is the standard L27 array, and from Table 6.6, the research applies actual values to develop the design of the experiment as shown in Table 6.10.

Table 6.10 Design of the experiment

Exp	Moisture	Speed	Low temperature	High temperature	Short breakdown	Long breakdown
1	10/30	10/120	10/20	20/100	10/40	60/300
2	10/30	10/120	10/20	20/100	20/140	120/400
3	10/30	10/120	10/20	20/100	40/280	240/500
4	10/30	25/200	15/40	40/200	10/40	60/300
5	10/30	25/200	15/40	40/200	20/140	120/400
6	10/30	25/200	15/40	40/200	40/280	240/500
7	10/30	40/360	20/80	60/300	10/40	60/300
8	10/30	40/360	20/80	60/300	20/140	120/400
9	10/30	40/360	20/80	60/300	40/280	240/500
10	25/180	10/120	15/40	60/300	10/40	120/400
11	25/180	10/120	15/40	60/300	20/140	240/500
12	25/180	10/120	15/40	60/300	40/280	60/300
13	25/180	25/200	20/80	20/100	10/40	120/400
14	25/180	25/200	20/80	20/100	20/140	240/500
15	25/180	25/200	20/80	20/100	40/280	60/300
16	25/180	40/360	10/20	40/200	10/40	120/400
17	25/180	40/360	10/20	40/200	20/140	240/500
18	25/180	40/360	10/20	40/200	40/280	60/300
19	40/280	10/120	20/80	40/200	10/40	240/500
20	40/280	10/120	20/80	40/200	20/140	60/300
21	40/280	10/120	20/80	40/200	40/280	120/400
22	40/280	25/200	10/20	60/300	10/40	240/500

23	40/280	25/200	10/20	60/300	20/140	60/300
24	40/280	25/200	10/20	60/300	40/280	120/400
25	40/280	40/360	15/40	20/100	10/40	240/500
26	40/280	40/360	15/40	20/100	20/140	60/300
27	40/280	40/360	15/40	20/100	40/280	120/400

6. Run the experiments and collect the results.

Results were collected by linking the Taguchi OA in Table 6.10 to the discrete-event simulation model of Line 12 (Table 6.5). These results are further used to investigate the effect of variability and to identify the opportunities for improvement. Based on the integration of DoE and des table 6.11 obtained which results with respect to selected KPI based on different levels of variability.

Table 6.11 Results of the 27 simulation runs

Experiment No	% Waiting	% Blocked	% Stopped	% Working	Throughput
1	10.05	29.58	19.82	40.54	255047
2	13.98	13.52	23.96	48.53	288645
3	7.65	6.06	23.09	63.20	219916
4	6.76	8.00	19.64	65.60	253462
5	4.67	4.97	15.66	74.70	286895
6	12.88	10.46	21.69	54.97	254379
7	5.22	4.66	24.84	65.29	287465
8	4.49	8.83	23.59	63.09	185966
9	11.72	14.73	14.88	58.66	219769

10	8.70	9.17	24.09	58.04	253191
11	9.04	8.91	14.30	67.75	253904
12	13.12	13.85	13.78	59.25	186426
13	8.42	6.88	17.64	67.06	287525
14	7.63	8.73	11.19	72.46	253763
15	6.87	4.66	19.42	69.05	287163
16	12.24	12.78	25.09	49.89	152497
17	6.27	13.36	14.65	65.72	286593
18	11.32	11.46	12.67	64.55	287172
19	7.16	7.26	17.62	67.96	253171
20	5.75	5.38	18.54	70.34	185557
21	6.50	9.18	15.98	68.34	285350
22	7.24	8.79	21.45	62.52	254072
23	9.58	10.02	23.80	56.60	219220
24	7.12	20.37	11.96	60.56	285069
25	7.17	23.18	17.13	52.52	252378
26	6.24	16.60	11.41	65.76	284352
27	8.64	24.98	10.83	55.56	284924

After applying the Taguchi OA, the research will analyse the results using a correlation to identify which key performance indicator is most affected. Then process improvement will be applied in the highly variable areas using the artificial intelligence tool rule-based system to reduce the effect of variability on the production line.

6.8 Step 7: Results Analysis

To identify which performance measures are most affected, the research used correlation analysis to identify the effect of five key performances (% waiting, % blocked, % stopped, % working and throughput) on each other i.e. Table 6.12.

Table 6.12 Correlation matrix (Pearson[n])

Variables	% Waiting	% Blocked	% Stopped	% Working	Throughput
% Waiting	**1**	0.292	0.093	–0.629	–0.224
%Blocked	0.292	**1**	–0.333	–0.715	0.083
% Stopped	0.093	–0.333	**1**	–0.350	–0.357
% Working	–0.629	–0.715	–0.350	**1**	0.219
Throughput	–0.224	0.083	–0.357	0.219	**1**

Table 6.10 shows the correlation between the performance measures. The correlation matrix shows that percent working is highly correlated with waiting, blocked and stopped. However, out of the given PMs, % stopped has shown the highest correlation with throughput. For example as shown in Table 6.3, percent stopped is represented by MTTR and MTTF, and that reduces the throughput. The main cause of stoppages is not complying with SOPs. Therefore, reducing the stoppages may improve the throughput and %working (see table 6.3).

Minitab is used to plot the effect of factors on % working. Figure 6.5 shows that % working is affected by factors such as speed, low temperature, high temperature and short breakdown.

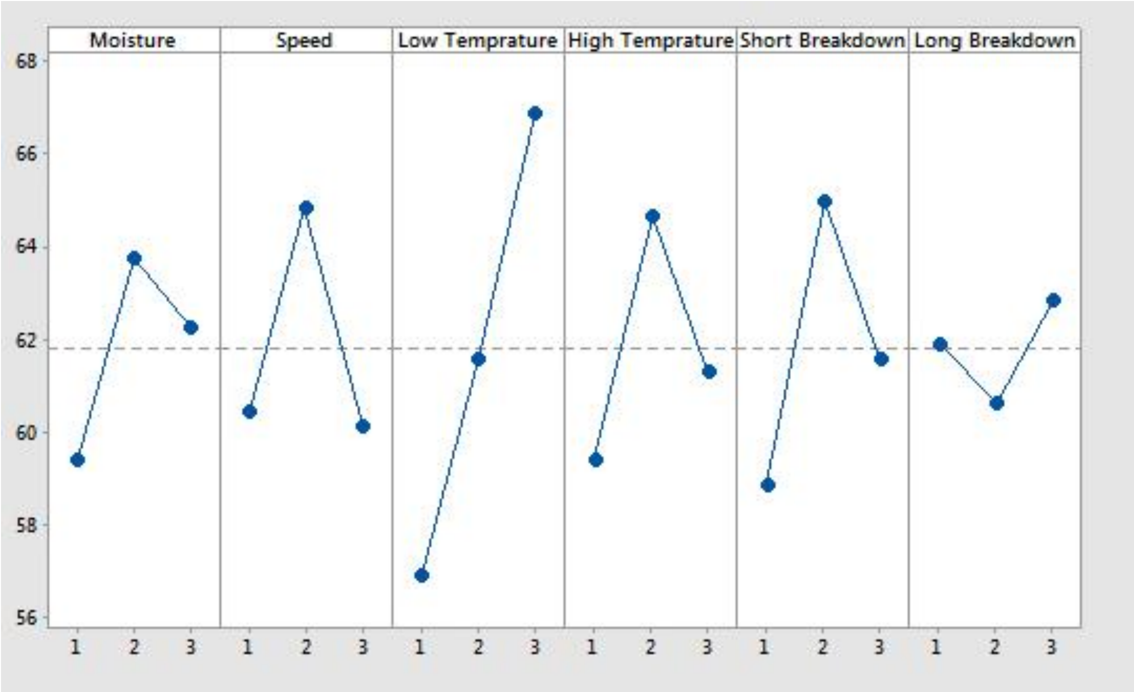


Figure 6.5 Factors that affect % working

6.9 Step 8: Rule-Based Approach

The rules come from Line 12 standard operating procedure (Appendix B), Line 12 work instructions (Appendix C), and tea biscuit product parameters (Appendix D).based on analysis (section 6.8) correlation matrices, the main cause of an increasing variability level is the process running out of standardisation. For example, Figure 6.5 shows high level of variability in low temperature. Therefore, the rule-based system was implemented to return the process into standardisation, as shown in the summary of the biscuit production line observation in section 6.5 and the summary of the rule-based system in Table 6.13. The rule-based system was implemented to change the process setting so it would match the standard setting provided by the manufacturer.

Based on the results of the Taguchi orthogonal array, as shown in Figure 6.5, % working is affected by several factors. In addition, as the factors were linked to the areas, as shown in Tables 6.2 and 6.4, the research highlighted the affected areas as follows:

- Low temperature increases biscuit moisture, and this reduces biscuit thickness. Reduction in biscuit thickness will in turn increase process defects and wastes as the stack of the biscuits cannot fit into the packet, and that increases stoppage in the packing machine which reduces % working in the packing area. The solution is to apply the rule-based system by adjusting the oven temperature to improve biscuit thickness. Biscuits bake gradually, and the oven consists of four zones. Each zone has a different temperature.
    - *Baking;* based on summery of observations on section 6.5, oven temperature is 115˚C and that considered as low temperature and it is out of oven work instructions (WI) limits (Appendix C). This causes uncooked biscuits and that result in increasing process waste (Appendix A) and reduced %working (section 7.2) as more biscuits are uncooked. The solution is to apply the rule-based system by increasing the oven temperature to match the standard, which is 180˚C as shown in section 6.5.

      Figure 6.6 shows the rule implementation to improve % working. The condition is that if operation time is equal to or more than five and % rework is equal to or more than 3%, then set the oven temperature to 180˚C and set MTTR = 10 and set MTTF = 60 to simulate the reflect of improvement in the real production line.

Area: Baking

Performance: % working

On breakdown

If oven temperature > 115°C

And % rework = 3

Then set oven temperature = 180°C

And set % rework = 1.5

And set MTTR = 10

And set MTTF = 60

Figure 6.6 improvement rule for Baking

- Speed is one of the factors that reduce work in the biscuit production line, and the affected areas are the cooling conveyor and packaging 1:
  - *Cooling conveyor;* based on summery of observations on section 6.5, cooling conveyor speed is 2.8 m/sec and that considered as low speed and it is out of SOP limit (Appendix B). This causes process waste and reduced %working as biscuits will jam in the conveyor and that affecting on increasing materials waste in baking (Appendix A) and decreases % working (section 7.2). The solution is to apply the rule-based system by increasing the conveyor speed to match the standard, which is 4 m/sec (section 6.5).

    Figure 6.7 shows the implementation of the rule-based system to improve working. The condition is that if operation time is equal to or more than five and % rework is equal to or more than 2%, then set the cooling conveyor speed to 4 m/sec and set MTTR = 20 and set MTTF = 700 to simulate the reflect of improvement in the real production line.

Area: Cooling conveyor Performance: % working On breakdown If cooling conveyor, operation time ≥ 5 And conveyor speed = 2.8 m/sec And % rework = 2 Then set conveyor speed = 4 m/sec And set % rework = 0.5 And set MTTR = 20 And set MTTF = 700

Figure 6.7 improvement rule for cooling conveyor

- *Packaging conveyor speed;* based on summery of observations on section 6.5, packaging conveyor speed is 1 m/sec and that considered as low speed and it is out of SOP limit (Appendix B). This causes process waste and reduced %working because of reduce synchronisation between packing and packaging which result in increasing materials waste (Appendix A) and decreases % working (section 7.2). The solution is to apply the rule-based system by increasing the conveyor speed to match the standard, which is 3 m/sec (section 6.5).

Figure 6.8 shows the implementation of the rule-based system to improve % working. The condition is that if operation time is equal to or more than three and % rework is equal to or more than 8%, then set the conveyor speed to 3 m/sec and set MTTR = 10 and set MTTF = 450 to simulate the reflect of improvement in the real production line.

Area: Packaging 1
Performance: % working
On breakdown
If packaging 1, operation time ≥ 3
And conveyor speed = 1 m/sec
And % rework = 8
Then set conveyor speed = 3 m/sec
And set MTTR = 10
And set MTTF = 450

Figure 6.8 improvement rule for Packaging 1

- High temperature is one of the factors that reduce work in the biscuit production line, and the affected area is packing machine 1*;*
    - *Packing machine 1;* based on summery of observations on section 6.5, packing machine 1 sealing temperature was 62˚C and that considered as high and it is out of packing WI limit (Appendix B). This causes bad sealing which result in increasing materials waste (Appendix A) and decreases % working (section 7.2). The solution is to apply the rule-based system by setting the machine temperature to match the standard, which is 56˚C as (section 6.5).

    Figure 6.9 shows that the implementation of the rule-based system aims to improve % working. The condition is that if operation time is equal to or more than two and % rework is equal to or more than 8%, then set the machine temperature to 56 and set MTTR = 15 and set MTTF = 350 to simulate the reflect of improvement in the real production line.

Area: Packing machine 1

Performance: % working

On breakdown

If packing machine 1, operation time ≥ 2

And machine temperature = 62°C

And % rework = 8

Then set machine temperature = 56°C

And set MTTR = 15

And set MTTF = 350

Figure 6.9 improvement rule for Packing machine 1

- Short breakdown results in decreased working in the biscuit production line, and the affected areas are aligning, packing machine 2 and packaging 2:
    - *Aligning;* some biscuits were sorted out of order and blocked the aligning queue. The solution is to close feeding and sort biscuits while machine running. Figure 6.10 shows that the implementation of the rule-based system aims to improve % working. The condition is that if operation time is equal to or more than four and % rework is equal to or more than 7%, then close feeding.

Area: Aligning

Performance: % working

On breakdown

If Aligning, operation time ≥ 4

And % rework = 7

Close feeding

Figure 6. 10 improvement rule for aligning

- *Packing machine 2;* based on summery of observations on section 6.5, packing machine 2 sensor stopped working and that considered as short breakdown. This causes machine stopped and that create biscuit jam in baking , cooling , and aligning which result in increasing materials waste (Appendix A) and decreases % working (section 7.2).

Figure 6.11 shows that the implementation of the rule-based system aims to improve % working. The condition is that if operation time is equal to or more than two and % rework is equal to or more than 9%, then set the sensor to 0.05 and set MTTF = 400 to simulate the reflect of improvement in the real production line.

Area: Packing machine 2
Performance: % working
On breakdown
If packing machine 2, operation time ≥ 2
And % rework = 9
Then set sensor = 0.05
And set MTTF = 400

Figure 6.11 improvement rule for packing machine 2

- *Packaging 2;* based on summery of observations on section 6.5, packaging2 fingers are out of timing and that considered as short breakdown. This causes damaging packets which result in increasing materials waste (Appendix A) and decreases % working (section 7.2).

The solution is to apply the rule-based system by increasing the packaging fingers to 20 packet/min.

Figure 6.12 shows that the implementation of the rule-based system aims to improve % working. The condition is that if operation time is equal to or more than three and % rework is equal to or more than 6%, then set the packing fingers to 20 packets/min and set MTTR = 10 and set MTTF = 450 to simulate the reflect of improvement in the real production line.

Area: Packaging 2

Performance: % working

On breakdown

If packaging 2, operation time ≥ 3

And packing finger = 15 packets/min

And % rework = 6

Then set packing finger = 20 packets/min

And set MTTR =10

And set MTTF =450

Figure 6.12 improvement rule for Packaging 2

Since the problem was identified, for process improvement, the research applied the rule-based system in order to improve each process that affected the factors. Therefore, after identifying the affected areas, the research implemented the improvements. Table 6.13 shows a summary of the affected factors and the improvements.

Table 6.13 Summary of the affected factors and the required improvements

Affected factors	**Workstation**	**Problem**	**Improvement**
Low temperature	Baking	Uncooked biscuits with low oven temperature in zone 1 oven is 160°C	Adjust heating temp to the standard heating temp in zone 1 = 180°C (+35 or – 10) keeping machine running and close-feeding
Speed	Cooling conveyor	Lower conveyor speed 2.8 m/sec	Increase conveyor speed 4 m/sec
	Packaging 1	Lower conveyor speed 1 m/sec	Increase conveyor speed 3 m/sec

High temperature	Packing machine 1	Bad sealing 62°C	Set machine temp 56°C
Short breakdown	Aligning	Biscuits out of order in the aligning queue, and this creates blocking	Close feeding queue and sort the biscuits while machine is running
	Packing machine 2	Sensor not working	Adjust sensor
	Packaging 2	Packaging finger out of timing 15 packet/min	Increase packaging finger to 20 packet/min

6.10 Conclusion

The research applied process mapping to understand the processes and identify value-added and non-value-added activities in the biscuit production line and then collected data and identified performance measures. Then this research developed a DES to mirror a real biscuit production line.

In order to identify different types of variability, the research applied DoE Taguchi orthogonal array to generate different scenarios using DES and then correlated the results. The highest correlated KPI identified was % working.

After the research identified the highest correlated KPI, the research identified the factors affected by the increasing variability in % working. The factors are moisture, speed, low temperature, high temperature, short breakdown and long breakdown. The research applied improvements using rule-based approach (used DES to validate the improvement before applying it in real life) in the affected areas, such as baking, cooling, aligning, packing and packaging. In the next chapter, this research will analyse the results and compare them before and after the improvement.

Chapter 7: Results and Analysis

7.1 Introduction

This chapter presents the experimental results on the basis of data collected through the methodology developed in Chapter 6. Initial and post-improvement results are collected using different levels of process variability such as moisture, speed, temperature and breakdowns (Table 6.6). All the results are presented with respect to the KPIs selected, that is, % waiting, % working, % stopped, % blocked and throughput.

Using initial experimental analysis, the results showed that % working is highly correlated with % waiting, % stopped, % blocked and throughput as shown in Table 6.12. However, % stopped showed the highest correlation with throughput. As mentioned in Table 6.3, % stopped is represented by MTTR and MTTF, i.e. failing more frequently will cause line more often and hence, reduces throughput.

After identifying highly correlated KPI, the research identified the levels of factors affecting % working. These factors were linked to the areas. Therefore, the research implemented improvement using rule-based approach in the affected areas to reduce factor effect by applying standardisation as shown in Table 6.13.

The proposed integrated methodology showed significant improvement by reducing variability in the food flow processing system as identified in Section 2.5.

7.2 Results Analysis

This section discusses the results collected using the proposed methodology. A clear abstraction is provided between the pre- and post-improvement results using Table 7.1 and Table 7.2. The results are collected for each experiment using simulation run time equals to 870,000 minutes. Simulation run time represents the manufacturing lead time as selected case study represents MTS environment. 870,000 minutes are equivalent to 5 months, as described in section6.5.

Table 7.1 Results of the simulation model before application of the rule-based system

Before						
Workstation	Workstation name	% Working	% Waiting	% Stopped	% Blocked	Throughput
1	Mixing	58.25	0.00	38.34	0.00	39,006
2	Dough cutter	10.25	0.01	50.08	38.44	17,877
3	Laminator	14.92	32.17	2.91	48.25	17,729
4	Roller cutter	4.08	19.23	2.42	74.02	17,729
5	Baking	43.77	5.07	39.40	6.74	17,570
6	Cooling conveyor	19.42	47.00	10.44	20.85	16,893
7	Aligning	9.53	34.67	43.24	12.56	16,560
8	Packing machine 1	2.92	18.12	74.43	4.19	7,611
9	Packing machine 2	2.96	18.92	74.43	4.19	7,762
10	Packaging 1	3.85	52.65	42.88	0.00	6,696
11	Packaging 2	4.01	52.37	42.98	0.00	6,975
12	Recycle grinding	7.42	7.42	3.65	0.00	4,299

Note: Total output = 12,581

Table 7.2 Results of the simulation model after application of the rule-based system

After						
Workstation	Workstation name	% Working	% Waiting	% Stopped	% Blocked	Throughput
1	Mixing	63.06	0.00	33.26	0.00	42,221
2	Dough cutter	18.81	0.01	4.56	74.37	32,767
3	Laminator	27.35	9.03	4.75	55.66	32,476
4	Roller cutter	7.47	3.39	3.22	85.47	32,476

5	Baking	48.55	0.23	39.40	6.25	32,163
6	Cooling conveyor	35.48	43.53	7.76	9.04	30,846
7	Aligning	9.88	30.88	43.24	15.99	30,234
8	Packing machine 1	5.42	15.93	71.29	6.71	14,182
9	Packing machine 2	5.33	15.85	71.29	6.71	13,925
10	Packaging 1	7.20	54.08	37.58	0.00	12,493
11	Packaging 2	7.17	54.00	37.70	0.00	12,452
12	Recycle grinding	13.64	13.64	3.65	0.00	7,915

Note: Total output = 22,937

Figures 7.1 to 7.5 compare the performance before and after the rule-based system implementation.

- **Working.** After implementation of the rule-based system, % working increased for all workstations because the effect of the factors decreased (Figure 7.1). For example, low temperature in baking (workstation 5), causes line to be stopped and hence decreased working (section 6.9). The improvement was implemented using rule-based approach by increasing the oven temperature to match the standard operating procedures as shown in Figure 6.7. Percent working in baking increased by 4.78.In addition, other workstations shows improvement such as laminator (workstation 3). However, high correlation (Section 6.8) between % working and % waiting was affected, reducing improvement in some areas such as mixing (workstation1), cutting (workstation4) and aligning (worstation7) as shown in Figure 7.1.

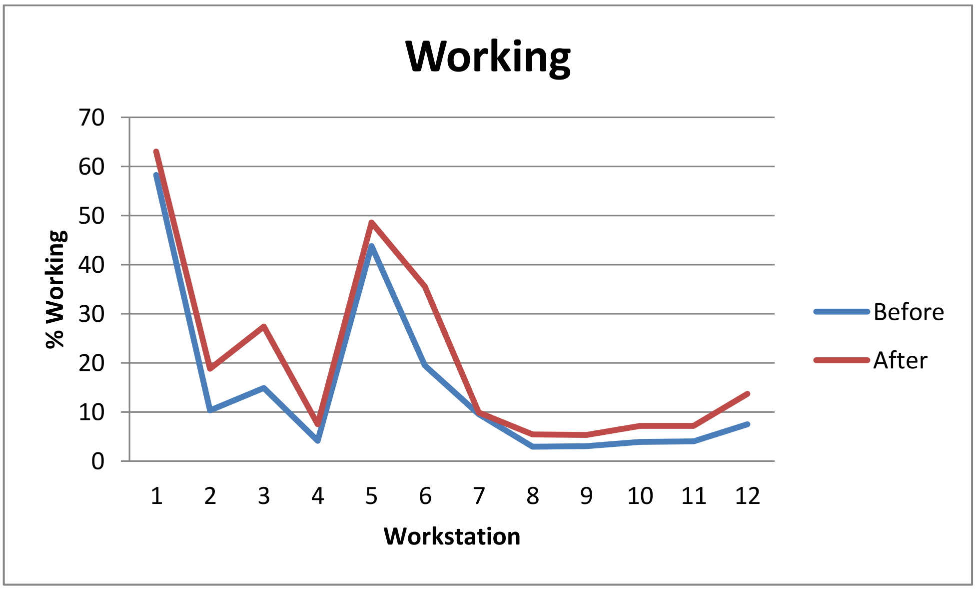


Figure 7.1 Percent working before and after improvement

- **Waiting.** After implementation of the rule-based system, percent waiting improved because the effect of the factors as shown in Figure 7.2. For example, aligning (workstation 7), some biscuits were sorted out of order and jammed. Jamming caused material wastes and increased the waiting in packing. This reduced the smooth movement in the aligning queue and increased waiting in packing machines. The rule-based system can be implemented by close-feeding and sorting the biscuits while the machine is running (section 6.9). Percent waiting in aligning decreased by 3.79.In addition, other workstations shows improvement such as cutter roller (workstation 4). However, high correlation (section 6.8) between working and waiting was affected, reducing improvement in some areas such as cooling conveyor (workstation 6) and packing machine 2 (workstation 9) as shown in figure 7.2.

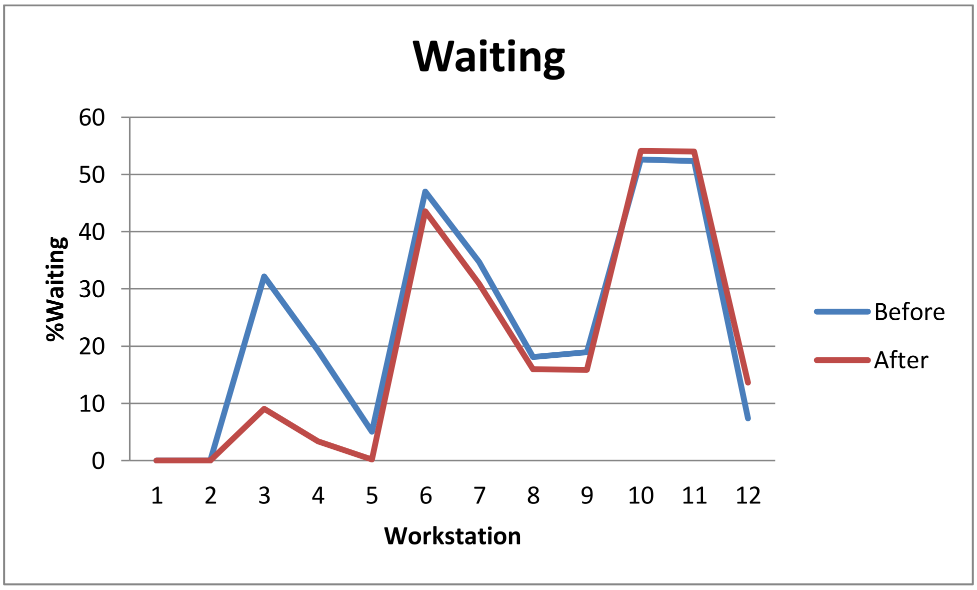


Figure 7.2 Percent waiting before and after improvement

- **Stopped.** After implementation of the rule-based system, the process improved, and the percent stopped decreased because the effect of the factors as shown in Figure 7.3. For example, sensor stopped working in packing machine 2. The improvement was implemented using rule-based approach by repairing and adjusting the sensor to match the standard (section 6.9). Percent stopped in packing machine 2 (workstation 9) decreased by 3.14. In addition, other workstations shows significant improvement such as dough cutter (workstation 2) as shown in figure 7.3.However, high correlation (section 6.8) between stopped and throughput was affected, reducing improvement in some areas such as laminator(workstation 3) , cutter roller (workstations 4) , and aligning (workstation 7).

Figure 7.3 Percent stopped before and after improvement

- **Blocked.** After implementation of the rule-based system, the process improved, and percent blocked decreased because of the effect of the factors as shown in Figure 7.4. For example, lower speed in cooling conveyor (workstation 6) that blocked cooling conveyor and increase wastes in baking and cooling conveyor. The improvement was implemented using rule-based approach by adjusting the conveyor speed to match the standard (section 6.9). Percent blocked in cooling conveyor decreased by 11.81. However, high correlation (section 6.8) between blocked and stopped was affected, reducing improvement in some areas such as dough mixing (workstation 1) , dough cutter (workstation 2) , and Laminating (workstation 3)

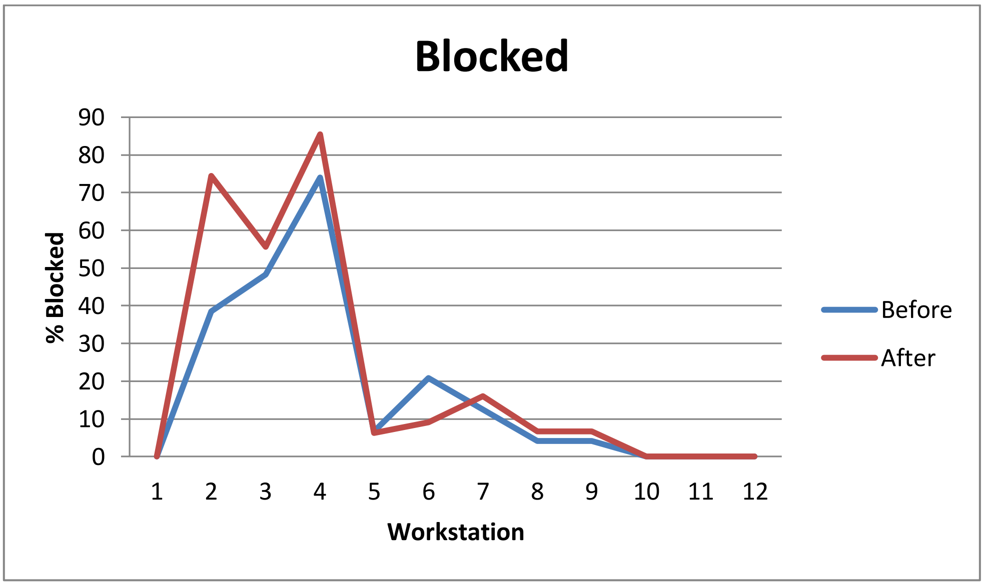


Figure 7.4 Percent blocked before and after improvement

- **Throughput.** After implementation of the rule-based system, throughput increased because the effect of the factors as shown in Figure 7.5. For example, high temperature in packing machine 1 (workstation 9) that cause bad sealing packets. The improvement was implemented using rule-based approach by setting the machine temperature to match the standard (section 6.9). Throughput in packing machine 1 increased by 6,571 units.

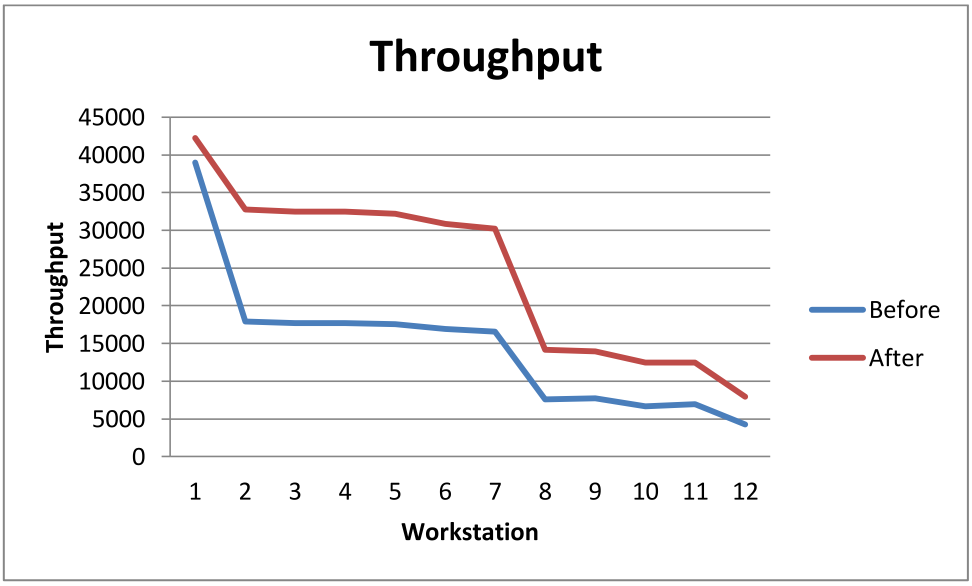


Figure 7.5 Throughput before and after improvement

7.3 Conclusion

The results showed that after implementation of the rule-based system, key performance improved in high variable areas. For example, percent working increased in baking by 4.78, percent waiting decreased aligning by 3.79, percent of stopped decreased in packing machine 2 by 3.14, percent of blocked decreased in cooling conveyor by 11.81, throughput increased in packing machine 1 by 6,571 and the objectives were achieved by identifying different types of variability on the highest affected KPI (section6.8) and improving high variable areas (section 6.9). However, high correlation between key performances affected in reduces improvement in some areas (section 6.8). For example, correlation between working and waiting was affected in reducing improvement in some areas such as cooling.

Based on the results, the next chapter will talk about the research question, novelty and contribution to knowledge in great detail.

Chapter 8: Discussion

8.1 Introduction

After implementation of an integrated method to reduce the different types of variability in the food production system and comparing the results before and after improvement, in this chapter, the research will discuss all approaches and methods in this thesis and the advantages of applying them in the food production system. Then the research will discuss the novelty and contribution to knowledge. After that, key improvements will be highlighted.

8.2 Why adopt lean in the food production system?

Based on literature review in Chapter 3, it has been identified that Lean philosophy can be equally applicable in food production systems. Section 3.4, categorised 7 wastes in context of biscuit production systems. Lean tools help clarifying wastes types to facilitate identify different types of variability (section 6.4) i.e. decreasing speed of cooling conveyor increase waiting time in packing (section 3.4) and that considered one of different types of variability in biscuit production . The improvement implemented by adjusting cooling conveyor speed to match standardisation (section 6.9).

The research highlighted process mapping a lean tool that can be applied in food production to understand the flow of processes , identify value-added and non-value-added activities , and category wastes in biscuit production line based on process mapping identification

As mentioned in Section 6.2, process mapping for a biscuit production line has helped the researcher to understand the process and activities involved in biscuit production and have helped factory stakeholders in improvement implementations. The research used process mapping as a guide to develop the DES.

8.3 Why a simulation model?

The main advantages of simulation are exemplified in Section 4.6. One of the main benefits of applying simulation in this particular case was to mimic the production process and maintain the continuous improvement culture. From the continuous improvement aspect, using simulation it is easy to focus on different processes as experiments can be done without interrupting the actual production process. For example, DoE require running 27 scenarios in biscuit production line. If the experiments applied directly in the shop floor that would interrupt normal production plan. Therefore, if the experiment run through simulation model, that would save time, effort, cost, and materials (section 6.7).

In addition, the research needed the simulation model to apply the Taguchi orthogonal array to generate different scenarios and investigate the effect of variability on the process (Section 6.5). Running a number of experiments on actual production line is infeasible; therefore integration between DES and DoE makes experimentation process feasible. Results analysis from DES and DoE allowed development of rules to improve the process (Section 6.9).

8.4 The advantages of the implementation of the Taguchi orthogonal array in food the production system

DoE allows development of experiments based on the number of factors and levels. In addition, The DoE has been applied to generate different scenarios and identify different types of variability that would give a quick response and a limited number of experiments (section 6.7).

Then the results were correlated to identify the highest correlated KPI (section6.8). The factors that affected the highest correlated performance were identified to apply improvement using rule-based approach in the highest variable areas (section 6.9).

8.5 Novelty of work

Investigating different types of variability in food production system can help in reduce wastes of time and materials, increase efficiency, and reduce cost (section 1.1). Researchers applied many techniques such as MILP, Pareto chart, neural network, full factorial design, and genetic algorithm (section 1.2, 4.8) to reduce the effect of variability on food processing systems. However, reducing the effect of variability is still a key challenge because different factor levels (section 1.1) have different effect on the food processing systems (section 6.8). Therefore, the interrelationship between the factors need to be considered to apply improvement in high variable areas.

The proposed approach addresses process time variability issues in food production system. Integrated process mapping, DES, DoE, and Rule-based approaches are combined in systematic and structured manner to investigate and reduce different types of variability in food production system. Integrated process mapping with DES provides the advantage over existing methods as process mapping (i) improved the understanding of the process and enabled the process owners to carry out improvement activities and (ii) enabled the implementation of DES. DES can be used in an iterative manner to identify other improvement opportunities.

The simulation model can mimic the manufacturing environment while the methodology remains the same and allows the implementation of different scenarios using Taguchi OA . Reduce different types of variability by integrating DES with rule-based to improve high variable areas and validated them before operating the real production line in order to save time, cost, and effort.

8.6 Contribution

The research collected data extensively for measuring materials and time wastes (i.e. breakdown duration and time between breaks) to identify different types of variability in food production system. Waste of time and materials measured in each breakdown. For example in this case, Table 6.1; Oven produces a lots of wastes, materials wastes was collected every three hours i.e. 380 kg from 8:30 am to 11:30 am was, and the total wastes was 446 kg with 41% of total wastes because of bad appearance biscuits that took 22 min 20 sec (section 6.3).

In addition, the research integrated method provides quick response that deals with reduced variability in food production system. Because of the use of DES, any changes to the process can be modelled, and data can be collected quickly to find the solution.

In addition, the integrated method focused on reducing variability in high variable areas, which narrowed the improvement in the required areas and increased its effectiveness. The evaluation of KPIs at each machine thereby improving the machine utilisation , reduce wastes of time and materials.

8.7 Result discussion

8.7.1 Key improvements

The key improvements of the system are as follows:

- Improved work in the biscuit production line as shown in Figure 7.1

- Increased throughput– improved performance can increase throughput as shown in figure 7.5.
- Improved food flow processing system – implementing the rule-based system that improves performance in the food flow processing system as shown in Section 6.9.
- Increased process stability – improved stability with reduction of % blocked as shown in Figure 7.3 and % stopped as shown in Figure 7.4.
- Reduce waste of time – by reducing waiting time in the system (Figure 7.2).

8.7.2What is the impact of other KPIs?

As mentioned in Section 7.1, other KPIs were slightly improved. Throughput increased, and waste was reduced. However, the correlation between KPIS was affected, which slightly reduces the improvement in the performance measures in some areas. For example, working correlated with waiting and that affected in reduce improvement in working in some areas such as cutter roller, baking, and aligning. Blocked correlated with stopped and that affected in reduce improvement in blocked in some areas such as cutter roller and baking.

8.8 Conclusion

Thus, as mentioned above, the research applied a integrate method for reducing variability in a biscuit production line. The research collected data exclusively for process output and breakdown activities, taking into account breakdown time and the root causes in each area.

Process mapping was applied to understand the process, identify value-added and non-value-added activities and enable DES implementation. DoE Taguchi OA used DES for generating different scenarios to save time, cost, effort, and material.

Improvement was implemented through rule-based approach in DES to validate the improvement before applying it in real life. The results showed improvement in key performances such as working, waiting, blocked, stopped and throughput as shown in Sections 7.2 and 8.8.1. In the next chapter, the research will discuss the conclusion of this thesis in great detail.

Chapter 9: Conclusion

9.1 Conclusion

In an attempt to improve the flow of food production system, the research engages in the detailed study of the production-based problems that could result from the different types of variability in the production line.

The research uses a biscuit production line as a case study. It addresses biscuit production line problems such as machine breakdown, variable temperature, and speed. The advantages of the proposed approach (section 6.1) follow:

- Improved process understanding though process mapping.
- Process mapping creates a process flow for identifying value-added and non-value-added activities and will help developing a discrete-event simulation (DES) model.
- A DES model will mimic the real world environment and will allow experimentation in a controlled environment without interrupting the production process.
- Taguchi OA will help to generate the reduced experiment set compared to full factorial approach in order to investigate the effect of variability on the food production system.
- Integrating the DES and DoE will facilitate running different scenarios, which will help in identifying the area and KPIs effected due to process time variability.

- Based on the correlation analysis and SOP process improvement rules will be developed and by integrating these rules with the DES model will allow to understand the effectiveness of proposed solution.

The proposed approach addresses process time variability issues in food production system. Integrated process mapping, DES, DoE, and Rule-based approaches are combined in systematic and structured manner to investigate and reduce different types of variability in food production system (section 8.5).

The research collected data extensively for measuring materials and time wastes to identify different types of variability in food production system. In addition, the research integrated method provides quick response that deals with reduced variability in food production system. Because of the use of DES, any changes to the process can be modelled, and data can be collected quickly to find the solution. Morvoer, the integrated method focused on reducing variability in high variable areas, which narrowed the improvement in the required areas and increased its effectiveness (section 8.6).

The research defines types of production systems in order to understand the flow of food (section 2.2). Food characteristics (section 2.3) and MTS-MTO (section 2.4 - 2.8) are highlighted to identify types of variability in food production system (section 2.10). Then the research adopts lean in food production system (section 3.1- 3.5), the application of waste categories, and process mapping (section 6.2).

The research develops a simulation model (section 6.6) to mirror the production line and applies different scenarios using Taguchi OA (section 6.7). The results are analysed by correlation and the research identifies %working as the highest performance variable.

Afterwards, the research analyse the results to identify the factors that result in decreases in working (section 6.8).

For process improvement, the research applies the artificial intelligence tool, the rule-based approach, to reduce the impact of the factors in high variability areas (section 6.9). After implementation, the results show variable improvement, increased working and throughput, and reduced waste. %working improved in baking by 4.78%, in cooling by 16.06%, in aligning by 0.35%, in packing machine1 by 2.5%, in packing machine2 by 2.37%, in packaging1 by 3.35%, and in packaging2 by 3.16%. However, the correlations between performance measures affect the improvements in some areas (section 7.2).

9.2 Recommendations and future work

The proposed framework can be enhanced further in the following ways:

- Based on the research case study requirements, Taguchi L27 OA allows the optimal set of experiments. However, this may not be the case with other scenarios. The proposed methodology can be extended by investigating different orthogonal array approaches based on the number of factors, the number of variables, and the level of variability.
- The proposed methodology focuses solely on the production problems that the machine parameters induce. However, variability in the supply chain can result from scheduling, planning, forecasting, and last minute orders. It is possible to extend the proposed approach to investigate these factors' effects.

- The proposed methodology considers some factors that affect the biscuit production line to a great extent. They include machine breakdown, variable temperature, and speed. However, other factors, such as due date, weather changes, and variable demand may increase process variability.

References

(2005) User Manuel Of Polyanalyst 5.

ADETUNJI, I. O. (2005) Achieving sustainability in the construction supply chain.

In Civil and Building Engineering .Loughbrough University, Loughbrough.

AKKERMAN, R. & VAN DONK, D. P. (2009) Product mix variability with correlated demand in two-stage food manufacturing with intermediate storage. *International Journal of Production Economics,*vol. 121, pp.313-322.

ARDON-FINCH J.P., STOCKTON, D. & KHALIL, R. (2008) Walk cycle design for flexible manpower lines. *International Journal of Computer Integrated Manufacturing,* vol.46, pp.2927-2943.

ARJONA, E., BUENO, G. & SALAZAR, L. (2001) An activity simulation model for the analysis of the harvesting and transportation systems of a sugarcane plantation. *Computers and Electronics in Agriculture,* vol. 32, pp. 247-264.

BAGIS, A. (2008) Fuzzy rule base design using tabu search algorithm for nonlinear system modeling. *ISA Transactions*, vol. 47, pp.32-44.

BEATHAM, S. (2003) *Development of an Integrated business Improvement System fo Construction,* Loughborough Loughbrough University.

BICHENO, J. (2000) *The lean Toolbox*, Buckingham, PICSIE Books.

CAPDEVILA, C., GARCIA-MATEO, C., CABALLERO, F. G. & GARCÍA DE ANDRÉS, C. (2006) Neural network analysis of the influence of processing on strength and ductility of automotive low carbon sheet steels. *Computational Materials Science,* vol.38, pp. 192-201.

CASTRO, P. A. D. & CAMARGO, H. A. (2004) Learning and optimization of fuzzy rule base by means of self-adaptive genetic algorithm. *Fuzzy Systems, 2004. Proceedings. 2004 IEEE International Conference.*vol.2. pp. 1037-1042.

CATTANI, K., DAHAN, E. & SCHMIDT, G. M. (2003) Using Make-to-Order Production Layered on Make-to-Stock Production to Hedge Against Uncertainty.vol. 21. pp. 435-567.

CLAYCOMB, C., DRÖGE, C. & GERMAIN, R. (2005) Applied customer knowledge in a manufacturing environment: Flexibility for industrial firms. *Industrial Marketing Management*, vol. 34, pp. 629-640.

CORTI, D., POZZETTI, A. & ZORZINI, M. (2006) A capacity-driven approach to establish reliable due dates in a MTO environment. *International Journal of Production Economics*, vol. 104, pp. 536-554.

CRESWELL, J. W. (2003) *Research Design*, London, Sage publications.

DAS, S. K. & ABDEL-MALEK, L. (2003) Modeling the flexibility of order quantities and lead-times in supply chains. *International Journal of Production Economics*, vol. 85, pp. 171-181.

DEMETER, K. & MATYUSZ, Z. (2010) The impact of lean practices on inventory turnover. *International Journal of Production Economics*, vol 2 . pp. 123-133.

DICKSON, E. W., SINGH, S., CHEUNG, D. S., WYATT, C. C. & NUGENT, A. S. (2009) Application of Lean Manufacturing Techniques in the Emergency Department. *The Journal of Emergency Medicine*, vol. 37, pp. 177-182.

DOGANIS, P. & SARIMVEIS, H. (2007) Optimal scheduling in a yogurt production line based on mixed integer linear programming. *Journal of Food Engineering*, vol. 80, pp. 445-453.

FERREIRA, D., MORABITO, R. & RANGEL, S. (2009) Solution approaches for the soft drink integrated production lot sizing and scheduling problem. *European Journal of Operational Research,* vol. 196, pp. 697-706.

FRANCO, L. A. & MONTIBELLER, G. (2010) Facilitated modelling in operational research. *European Journal of Operational Research*, vol. 205, pp. 489-500.

FRANSOO, C. & WOUTERS, M. (2000) Measuring the bullwhip effect in the supply chain. *International Journal,* vol. 5, pp. 78-89.

GERMAIN, R., CLAYCOMB, C. & DRÖGE, C. (2008) Supply chain variability, organizational structure, and performance: The moderating effect of demand unpredictability. *Journal of Operations Management,* vol. 26, pp. 557-570.

GRAZIANO, A. M. & L.RAULIN, M. (2004) *Research Methods : a Process of Inquiry,* Boston, Pearson Education Group GREASLEY, A. (2006) Using process mapping and business process simulation to support a process-based approach to change in a public sector organisation. *Technovation,* vol. 26, pp. 95-103.

GÜRBÜZ, F. (2010) Comparison Of Polyanalyst Prediction Techniques Using Different Data Sets. *Continuous Optimization and Information-Based Technologies in the Financial Sector.* Izmir, TURKEY, Izmir University of Economics. vol.1 . pp. pp. 248–253

HANCOCK, B. (1998) *Trent Focus for Research and Development in Primary Health Care:An Introduction to Qulitative Research,* Nottingham, Trent Focus.

HIGGINS, A. & DAVIES, I. (2005) A simulation model for capacity planning in sugarcane transport. *Computers and Electronics in Agriculture,* vol. 47, pp. 85-102.

HOPP, W. & SPEARMAN, M. (2001) *Factory Physics,* New York, Irwin/McGraw-Hill Press.

HUDA, A. M. & CHUNG, C. A. (2002) Simulation modeling and analysis issues for high-speed integrated continuous and discrete food industry manufacturing processes. *Computers & Industrial Engineering,* 43**,** 473-483.

HUND, E., MASSART, D. L. & SMEYERS-VERBEKE, J. (2001) Operational definitions of uncertainty. *TrAC Trends in Analytical Chemistry,* vol. 20, pp. 394-406.

IERAPETRITOU, M. G. & FLOUDAS, C. A. (1998) Effective Continuous-Time Formulation for Short-Term Scheduling. 1. Multipurpose Batch Processes. *Industrial & Engineering Chemistry Research,* vol. 37, pp. 4341-4359.

IQBAL, A. & DAR, N. U. (2011) Optimal formation of fuzzy rule-base for predicting process's performance measures. *Expert Systems with Applications,* vol. 38, pp. 4802-4808.

JAFARI, A., TYNJALA, T., MOUSAVI, S. M. & SARKOMAA, P. (2008) CFD simulation and evaluation of controllable parameters effect on thermomagnetic convection in ferrofluids using Taguchi technique. *Computers & Fluids,* vol. 37, pp. 1344-1353.

JANKOWICZ, A. D. (2005) *Business Research Projects,* London, Thomson Learning.

JAVORSKY, J., FRANCHETTI, M. & ZHANG, H. (2013) Determining the optimal parameters of bonding polyvinylchloride to stainless steel in automotive applications with the use of full factorial design of experiment. *CIRP Journal of Manufacturing Science and Technology,* 7**,** 151-158.

JACXSENS, L., LUNING, P. A., VAN DER VORST, J. G. A. J., DEVLIEGHERE, F., LEEMANS, R. & UYTTENDAELE, M. (2009) Simulation modelling and risk assessment as tools to identify the impact of climate change on microbiological food safety - The case study of fresh produce supply chain. *Food Research International,* In Press, Corrected Proof.

JUTRAS, P., PRASHER, S. O. & MEHUYS, G. R. (2009) Prediction of street tree morphological parameters using artificial neural networks. *Computers and Electronics in Agriculture,* vol. 67, pp. 9-17.

KAMINSKY, P. & KAYA, O. (2009) Combined make-to-order/make-to-stock supply chains. *IIE Transactions,* vol. 41, pp. 103-119.

KANG, P. S., Duffy, A., Shires, N., Smith, T. and Novels M. (2014) Lean Cables – A Step towards Competitive, Sustainable and Profitable Processes. Proceedings of the 63rd IWCS Conference, RI, USA, (Nov 2014), pp. 310 - 317.

KANG , P. , ABOUTALEB , A. , SILVA ,C., ERHART , A., TODESCHINI ,V., & DUFFY, A. (2015) Process Control Parameters Evaluation Using Discrete Event Simulation for Business Process Optimization *64th International Wire & Cable Symposium Conference* Atlanta , USA, IWCS, Inc, pp. 569-577

KANG, P. S., Erhart, A., Todeschini, V., and Duffy, A., (2015)"Comparative Study of Two Scheduling Approaches to Resolve the Scheduling Problem for a Wire and Cable Manufacturing Process", 7th Biennial Cable and Wire Technical Conference, Dusseldorf, Germany, Nov. 2015.

KANG, P. (2012) *Improving Manufacturing Systems Using Integrated Discrete Event Simulation and Evolutionary Algorithms*. PhD thesis, De Montfort University.

KVALE , S. (1996) Interviews An Introduction to Qualitative Research Interviewing, Sage Publications.

KHALIL, R. (2005) *Predicating the effect of variability on the efficiency of flow processing system*. PhD theasis, De Montfort University

KHAW, J. F. C., LIM, B. S. & LIM, L. E. N. (1995) Optimal design of neural networks using the Taguchi method. Neurocomputing, vol. 7, pp. 225-245.

KOPANOS, G. M., PUIGJANER, L. & GEORGIADIS, M. C. (2010) Optimal production scheduling and lot-sizing in dairy plants: The yogurt production line. *Industrial and Engineering Chemistry Research,* vol. 49, pp. 701-718.

KOPANOS, G. M., PUIGJANER, L. & MARAVELIAS, C. T. (2011) Production planning and scheduling of parallel continuous processes with product families. *Industrial and Engineering Chemistry Research,* vol. 50, pp. 1369-1378.

KUMAR, R. (2005) *Research methodology: A step-by-step guide for beginners,* London, SAGE Publications Ltd.

LIU, J., MARTINEZ, L., CALZADA, A. & WANG, H. (2013) A novel belief rule base representation, generation and its inference methodology. *Knowledge-Based Systems,* vol. 53, pp. 129-141.

LUND, D. (2003) Predicting the impact of food processing on food constituents. *Journal of Food Engineering,* 56**,** 113-117.

MCNAMARA,C. (1999) General Guidelines for Conducting Interviews, Minnesota, Minnesota University.

MELTON, T. (2005) The Benefits of Lean Manufacturing: What Lean Thinking has to Offer the Process Industries. *Chemical Engineering Research and Design,* vol. 83, pp. 662-673.

MENDEZ, C. A. & CERDÁ, J. (2004) An MILP framework for batch reactive scheduling with limited discrete resources. *Computers & Chemical Engineering,* vol. 28, pp. 1059-1068.

MINITAB (2015) Factorial designs. Mintab.

MODELL, S. (2009) In defence of triangulation: A critical realist approach to mixed methods research in management accounting. *Management Accounting Research,* vol. 20, pp. 208-221.

NELSON, R., KOKIC, P., CRIMP, S., MEINKE, H. & HOWDEN, S. M. (2009) The vulnerability of Australian rural communities to climate variability and change: Part I--Conceptualising and measuring vulnerability. *Environmental Science & Policy,* vol. 13, pp. 8-17.

PEREIRA, Z. L. & ASPINWALL, E. (1992) Taguchi methods in food processing. *Automation and Control in Food Processing, IEE Colloquium on.* vol.1. pp.1-7.

PREECE, R. (1994) *Starting Research : An Introduction to Academic Research and Dissertation Writing,* London, Pinter Publishers.

RADHARAMANAN, R. & ANSUJ, A. (2000) Quality Improvement of a Production Process Using Taguchi Methods. *International prodution confrence* . vol.2 . pp.170-180.

RIDLEY, D. (2008) *The Literature Review : A Step-by-Step giude for Students,* London, SAGE Publication Ltd.

ROBINSON, S., WORTHINGTON, C., BURGESS, N. & RADNOR, Z. J. (2014) Facilitated modelling with discrete-event simulation: Reality or myth? *European Journal of Operational Research,* vol. 234, pp. 231-240.

ROE, B., PAPAGEORGIOU, L. G. & SHAH, N. (2005) A hybrid MILP/CLP algorithm for multipurpose batch process scheduling. *Computers & Chemical Engineering,* vol. 29, pp. 1277-1291.

SARAVACOS, G. D. & KOSTAROPOULOS, A. E. (1996) Engineering properties in food processing simulation. *Computers & Chemical Engineering,* vol. 20, pp. S461-S466.

SCHIKORA, P. F. & GODFREY, M. R. (2003) Efficacy of end-user neural network and data mining software for predicting complex system performance. *International Journal of Production Economics,* vol. 84, pp. 231-253.

SHUKLA, S. K., TIWARI, M. K., WAN, H.-D. & SHANKAR, R. (2010) Optimization of the supply chain network: Simulation, Taguchi, and Psychoclonal algorithm embedded approach. *Computers & Industrial Engineering,* vol. 58, pp. 29-39.

SIMONS, D. & ZOKAEI, K. (2005) Application of lean paradigm in red meat processing. *British Food Journal,* vol. 107, pp. 192-211.

SOMAN, C. A., PIETER VAN DONK, D. & GAALMAN, G. (2006) Comparison of dynamic scheduling policies for hybrid make-to-order and make-to-stock production systems with stochastic demand. *International Journal of Production Economics,* vol. 104, pp. 441-453.

SOMAN, C. A., VAN DONK, D. P. & GAALMAN, G. (2004) Combined make-to-order and make-to-stock in a food production system. *International Journal of Production Economics,* vol. 90, pp. 223-235.

SOMAN, C. A., VAN DONK, D. P. & GAALMAN, G. J. C. (2007) Capacitated planning and scheduling for combined make-to-order and make-to-stock production in the food industry: An illustrative case study. *International Journal of Production Economics,* vol. 108, pp. 191-199.

STAATS, B. R., BRUNNER, D. J. & UPTON, D. M. (2011) Lean principles, learning, and knowledge work: Evidence from a software services provider. *Journal of Operations Management,* vol. 29, pp. 376-390.

TAJ, S. (2005) Applying lean assessment tools in Chinese hi-tech industries. *Management Decision,* vol. 43, pp. 628-643.

TAJ, S. (2008) Lean manufacturing performance in China: assessment of 65 manufacturing plants. *Manufacturing Technology Management Decision,* vol. 19, pp. 217-234.

TRENTESAUX, D., PESIN, P. & TAHON, C. (2001) Comparison of constraint logic programming and distributed problem solving: a case study for interactive, efficient and practicable job-shop scheduling. *Computers & Industrial Engineering,* vol. 39, pp. 187-211.

VAN DER VORST, J. G. A. J., BEULENS, A. J. M. & VAN BEEK, P. (2000) Modelling and simulating multi-echelon food systems. *European Journal of Operational Research,* vol. 122, pp. 354-366.

VAN DONK, D. P. (2001) Make to stock or make to order: The decoupling point in the food processing industries. *International Journal of Production Economics,* vol. 69, pp. 297-306.

VAN WEZEL, W., VAN DONK, D. & GAALMAN, G. (2006) The planning flexibility bottleneck in food processing industries. *Journal of Operations Management,* vol. 24, pp. 287-300.

WOMACK, J. & JONES, D. (2003) *Lean Thinking: Banish Waste and Create Wealth in Your Corporation,* London, Simon & Schuster UK Ltd.

WU, M.-C., JIANG, J.-H. & CHANG, W.-J. (2008) Scheduling a hybrid MTO/MTS semiconductor fab with machine-dedication features. *International Journal of Production Economics,* vol. 112, pp. 416-426.

YOUSSEF, K. H., VAN DELFT, C. & DALLERY, Y. (2004) Efficient Scheduling Rules in a Combined Make-to-Stock and Make-to-Order Manufacturing System. *Annals of Operations Research,* vol. 126, pp. 103-134.

ZAERPOUR, N., RABBANI, M., GHAREHGOZLI, A. H. & TAVAKKOLI-MOGHADDAM, R. (2008) Make-to-order or make-to-stock decision by a novel hybrid approach. *Advanced Engineering Informatics,* vol. 22, pp. 186-201.

ZAREI, M., FAKHRZAD, M. B. & JAMALI PAGHALEH, M. (2011) Food supply chain leanness using a developed QFD model. *Journal of Food Engineering,* vol. 102, pp. 25-33.

ZORZINI, M., CORTI, D. & POZZETTI, A. (2008) Due date (DD) quotation and capacity planning in make-to-order companies: Results from an empirical analysis. *International Journal of Production Economics,* vol. 112, pp. 919-933.

Appendix

Appendix A data Collection

Data collection based on observation for 5 months of biscuit production line 12 that include measuring waste of material and time include breakdown and root causes.

Line 12 Waste(kg) Commissioning 31/1/2006						
Process	Activity	Time			Total	Comment
		7-11:30 am	11:30-4:30pm	4:30-6:30pm		
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	
Laminating	Laminator	5.00	12.00	6.00	23.00	
	Press 1	2.00	5.00	3.00	10.00	
	Press 2	1.00	6.00	5.00	12.00	
	Press 3	10.00	9.00	4.00	23.00	
Oven	After oven	358	8.00	5.00	371.00	Total Process waste = 439 kg , 54% of waste
Cooling	Slide	0	1.00	0.00	1.00	
	By-Pass	45.90	5.00	2.00	52.90	
	Penny st. Guids1	3.00	2.00	0.50	5.50	
	Penny st. Guids2	3.00	2.00	0.50	5.50	
Aligning	Vibrator 1	1.00	0.50	0.20	1.70	
	Vibrator 2	0.50	0.50	0.21	1.21	
	Guide Bars Chine1	8.00	8.00	3.50	19.50	

	Guide Bars Chine2	10.00	10.00	0.40	20.40	
	Guide Conveyer1	0.4	2.00	0.00	2.40	
	Guide Conveyer2	0	0.00	0.00	0.00	
Packing1	Cavana 1	18.75	22.55	60.20	101.50	Wrapper Cutting problems 12 min 30 sec
Packing2	Cavana 2	15.40	27.75	63.10	106.25	Wrapper Cutting problems 11 min 20 sec
Packaging1	end seal 1	1.00	5.00	18.00	24.00	Seal problems 13 min 21 sec
Pqckaging2	end seal 2	19.60	2.00	10.40	32.00	Total Packing waste = 373 kg , 45% of waste
Total waste		502.55	128.30	182.01	812.86	
Accept Products		3880.85	4697.87	3472.34	12051.06	
Total		4383.40	4826.17	3654.35	12863.92	
Line Efficiency %		88.5	97.3	95.0	93.7	
Waste %		11.5	2.7	5.0	6.3	

Line 12 Waste (kg) Commissioning 1/2/06

Process	Activity	Time				Total	Comment
		7:45-10 am	10-12:15 am	1-3 pm	3-6 pm		
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	5.00	6.00	11.60	2.00	24.60	
	Press 1	1.00	1.00	2.50	1.00	5.50	
	Press 2	1.00	0.00	2.00	1.00	4.00	

	Press 3	0.00	2.00	2.00	1.00	5.00	
Oven	After oven	140	6.00	5.00	9.00	160.00	Bad Appearance burn biscuits 20 min 30 sec
Cooling	Slide	1	0.50	0.05	0.05	1.60	Total Process waste = 416.1, 63.17 % of waste 15 min 20 sec
	By-Pass	140.00	35.00	32.00	10.00	217.00	Bad Appearance burn biscuits from oven 20 min 40 sec
	Penny st. Guids1	0.20	0.10	0.05	0.05	0.40	
	Penny st. Guids2	0.20	0.10	0.02	0.02	0.34	
Aligning	Vibrator 1	0.50	0.05	0.10	0.10	0.75	
	Vibrator 2	0.40	0.05	0.01	0.10	0.56	
	Guide Bars Chine1	3.00	5.00	1.00	10.00	19.00	
	Guide Bars Chine2	4.00	6.00	13.50	10.00	33.50	
	Guide Conveyer1	1	0.20	0.00	0.00	1.20	
	Guide Conveyer 2	0	0.20	0.00	0.00	0.20	
Packing1	Cavana 1	28.00	5.00	15.00	32.00	80.00	
Packing2	Cavana 2	13.00	7.00	20.00	35.00	75.00	
Packaging1	end seal 1	5.00	2.00	2.00	5.00	14.00	
Packaging2	end seal 2	5.00	2.00	4.00	5.00	16.00	Total Packing Waste = 242.5, 36.8 % of waste
Total waste		348.30	78.20	110.83	121.32	658.65	
Accept Products		1634.04	3268.08	2859.57	4085.10	11846.79	
Total		1982.34	3346.28	2970.40	4206.42	12505.44	
Line Efficiency %		82.4299	97.6631	96.2689	97.1158	94.7331	

Waste %	17.5701	2.33692	3.73115	2.88416	5.26691	

Line 12 Waste in (kg) Commissioning 2/2/06

Process	Activity	Time				Total	Comment
		8-10 am	10-1 pm	1-3 pm	3-6 pm		
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	7.00	3.00	4.00	5.00	19.00	
	Press 1	12.00	0.00	1.00	1.70	14.70	
	Press 2	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	80	19.00	14.00	17.00	130.00	Total Process Waste = 163.7 , 38.15 % of waste
Cooling	Slide	0.1	0.00	0.10	0.10	0.30	
	By-Pass	41.00	3.00	12.00	40.00	96.00	Cavana Cutter problems 25 min 20 sec
	Penny st. Guids1	0.20	0.50	0.10	0.10	0.90	
	Penny st. Guids2	0.20	0.10	0.00	0.00	0.30	
Aligning	Vibrator 1	0.00	0.00	0.10	0.10	0.20	
	Vibrator 2	0.00	0.10	0.50	0.10	0.70	
	Guide Bars Chine1	4.00	1.00	0.50	0.10	5.60	
	Guide Bars Chine2	15.00	2.00	1.00	1.00	19.00	
	Guide Conveyer1	0	0.00	0.50	0.00	0.50	
	Guide Conveyer2	2	1.00	1.00	0.00	4.00	

Packing1	Cavana 1	15.00	1.00	10.00	14.00	40.00	
Packing2	Cavana 2	15.00	2.00	8.00	10.00	35.00	
Packaging1	end seal 1	4.00	0.50	2.00	20.00	26.50	
Packaging2	end seal 2	13.00	0.50	1.00	22.00	36.50	Total Packing Waste = 265.5 , 61.86% of waste
Total waste		208.50	33.70	55.80	131.20	429.20	
Accept Products		2042.55	3676.59	3839.99	3839.99	15055.20	
Total		2251.05	3710.29	3895.79	3971.19	15484.40	
Line Efficiency %		90.7377	99.0917	98.5677	96.6962	97.2282	
Waste %		9.26234	0.90828	1.43232	3.3038	2.77182	

Line 12 Waste (kg) Commissioning 5/2/06								
Process	Activities	Time				Total	% of Waste	Comment
		7-10 am	9-1 pm	1-3 pm	3-6:45 pm			
Mixing	Magnetic detector		0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator		7.50	4.50	5.00	17.00	3.25	
	Press 1		5.80	5.00	2.00	12.80	2.45	
	Press 2		0.00	0.00	0.00	0.00	0.00	
	Press 3		0.00	0.00	0.00	0.00	0.00	
Oven	After oven		160.00	2.00	3.00	165.00	31.53	Bad Appearance (Burn Biscuit) 24 min 20 sec

Cooling	Slide		0.10	0.12	0.00	0.22	0.04	
	By-Pass		60.00	50.00	50.00	160.00	30.58	
	Penny st. Guids1		0.10	0.20	0.10	0.40	0.08	
	Penny st. Guids2		0.00	0.10	0.10	0.20	0.04	
Aligning	Vibrator 1		0.00	0.10	0.30	0.40	0.08	
	Vibrator 2		0.00	0.20	0.15	0.35	0.07	
	Guide Bars Chine1		2.00	1.00	1.00	4.00	0.76	
	Guide Bars Chine2		3.00	2.00	4.00	9.00	1.72	
	Guide Conveyer1		0.30	0.10	0.10	0.50	0.10	
	Guide Conveyer2		0.20	0.10	0.10	0.40	0.08	
Packing1	Cavana 1		12.00	7.00	11.00	30.00	5.73	
Packing2	Cavana 2		10.00	15.00	20.00	45.00	8.60	
Packaging1	end seal 1		9.00	11.00	10.00	30.00	5.73	
Packaging2	end seal 2		13.00	20.00	15.00	48.00	9.17	
Total waste			283.00	118.42	121.85	523.27		
Accept Products			3436.29	3892.86	3594.89	12274.20		
Total			3719.29	4011.28	3716.74	12797.47		
Line Efficiency %			92.391	97.0478	96.7216	95.9111		
Waste %			7.60898	2.95217	3.27841	4.08886		

Line 12 Waste (kg) Commissioning 6/2/06								
Process	Activity	Time				Total	Waste %	Comment
		7-10 am	10-1 pm	1-3 pm	3-6 pm			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	5.00	3.00	3.00	3.00	15.00	4.70	
	Press 1	4.00	5.00	4.00	4.00	17.00	5.33	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	40	2.00	3.00	75.00	120.00	37.59	Total Process Waste = 149.9 , 47.3 % of waste
Cooling	Slide	0.1	0.00	0.00	0.00	0.10	0.03	
	By-Pass	0.50	0.00	0.00	40.50	41.00	12.84	
	Penny st. Guids1	1.00	0.00	0.00	0.00	1.00	0.31	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.10	0.00	0.00	0.00	0.10	0.03	
	Vibrator 2	0.00	0.00	0.00	5.00	5.00	1.57	
	Guide Bars Chine1	4.00	1.00	1.00	3.00	9.00	2.82	
	Guide Bars Chine2	4.00	2.00	1.00	2.00	9.00	2.82	
	Guide Conveyer1	0	0.00	0.00	0.00	0.00	0.00	
	Guide Conveyer2	0	0.00	0.00	0.00	0.00	0.00	
Packing1	Cavana 1	13.00	4.00	2.00	10.00	29.00	9.09	
Packing2	Cavana 2	10.00	3.00	3.00	12.00	28.00	8.77	

Packaging1	end seal 1	15.00	5.00	5.00	2.00	27.00	8.46	
Packaging2	end seal 2	4.00	4.00	5.00	5.00	18.00	5.64	Total Packing Waste = 167.2 , 52.7 % of waste
Total waste		100.70	29.00	27.00	161.50	319.20		
Accept Products		2451.06	2451.06	3964.95	3450.71	12317.78		
Total		2551.76	2480.06	3991.95	3612.21	12636.98		
Line Efficiency %		96.0537	98.8307	99.3236	95.5291	97.4741		
Waste %		3.9463	1.16933	0.67636	4.47095	2.52592		

Line 12 Waste (kg) Commissioning 7/2/06

Process	Activities	Time								Total	Waste %	Comment
		8:30-11:30am	11:30-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	5.00	3.00	2.00	4.00	3.00	20.00	1.85	
	Press 1	3.00	2.00	2.00	3.00	3.00	5.00	5.00	1.00	24.00	2.22	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	380	20.00	10.00	5.00	2.00	3.00	25.00	1.00	446.00	41.22	Bad appearance 22 min 20 sec
Cooling	Slide	2	0.00	0.00	0.00	0.00	0.00	0.00	0.50	2.50	0.23	
	By-Pass	70.00	0.00	0.00	25.00	35.00	96.00	5.00	65.00	296.00	27.35	Cavana2 Sealing problem in shift B 24 min 30 sec

	Penny st. Guids1	0.10	0.20	0.10	0.00	0.20	0.30	0.00	0.00	0.90	0.08	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.10	1.00	0.00	0.00	1.10	0.10	
Aligning	Vibrator 1	0.50	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.70	0.06	
	Vibrator 2	0.40	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.70	0.06	
	Guide Bars Chine1	15.00	0.00	1.00	3.00	4.00	1.00	1.00	1.00	26.00	2.40	
	Guide Bars Chine2	15.00	0.00	2.00	4.00	5.00	1.00	9.00	1.00	37.00	3.42	
	Guide Conveyer1	0	0.10	0.00	0.00	0.00	2.00	0.40	0.00	2.50	0.23	
	Guide Conveyer2	0	0.10	0.00	0.00	0.00	0.00	0.50	0.00	0.60	0.06	
Packing1	Cavana 1	0.50	4.00	15.00	0.00	10.00	35.00	5.00	0.10	69.60	6.43	
Packing2	Cavana 2	0.50	0.00	13.00	0.00	8.00	35.00	4.00	35.00	95.50	8.83	Sealing problem in shift B 25 min 40 sec
Packaging1	end seal 1	10.00	3.00	4.00	0.00	10.00	4.00	1.00	0.00	32.00	2.96	
Packaging2	end seal 2	7.00	4.00	2.00	0.00	10.00	3.00	1.00	0.00	27.00	2.50	
Total waste		505.00	34.40	50.10	45.00	90.50	188.60	60.90	107.60	1082.10		
Accept Products		2776.8	3310.80	2776.80	2883.60	3268.10	3449.64	3449.64	2178.72	24094.10		
Total		3281.80	3345.20	2826.90	2928.60	3358.60	3638.24	3510.54	2286.32	25176.20		
Line Efficiency %		84.6	99.0	98.2	98.5	97.3	94.8	98.3	95.3	95.7		
Waste %		15.4	1.0	1.8	1.5	2.7	5.2	1.7	4.7	4.3		
Total Process Waste = 490 , 45.3% of waste												
Total Packing Waste = 592.1 , 54.7% of waste												

Line 12 Waste (kg) Commissioning 8/2/06												
stage	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnatic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Laminator	1.00	1.00	1.00	5.00	4.00	5.00	5.00	5.00	27.00	3.24	
	Press 1	1.00	1.00	1.00	3.00	6.00	3.00	3.00	2.00	20.00	2.40	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	1	2.00	4.00	3.00	50.00	5.00	1.00	0.00	66.00	7.92	Bad appearance
conveyers	Slide	0	0.50	0.00	0.00	0.00	0.00	0.00	0.10	0.60	0.07	
	By-Pass	16.00	35.00	32.00	10.00	25.00	25.00	205.00	25.00	373.00	44.77	Products raken off line due to Cavana2 Sealing problem in shift B
	Penny st. Guids1	0.10	0.00	0.00	0.00	0.10	0.10	0.20	0.00	0.50	0.06	
	Penny st. Guids2	0.50	0.00	5.00	0.00	0.00	0.10	0.20	0.00	5.80	0.70	
	Vibrator 1	0.10	0.00	0.00	0.00	0.00	0.10	0.10	0.20	0.50	0.06	
	Vibrator 2	0.50	0.00	0.00	0.00	0.00	0.10	0.05	0.05	0.70	0.08	
	Guide Bars Chine1	0.10	0.50	0.00	0.00	2.00	0.10	5.00	3.00	10.70	1.28	
	Guide Bars Chine2	0.50	0.50	0.00	0.00	3.00	3.00	3.00	3.00	13.00	1.56	
	Guide Convoyer1	0.5	0.10	2.00	0.50	1.00	0.10	0.00	0.00	4.20	0.50	
	Guide Convoyer2	0.5	0.50	0.00	0.00	0.00	0.10	0.00	0.00	1.10	0.13	
packing	Cavana 1	12.00	18.00	22.00	8.00	15.00	15.00	25.00	10.00	125.00	15.00	
	Cavana 2	11.00	13.00	35.00	6.00	15.00	10.00	25.00	0.00	115.00	13.80	Sealing problem in shift B
	end seal 1	0.00	5.00	2.00	0.00	2.00	10.00	15.00	0.00	34.00	4.08	

	end seal 2	0.00	3.00	6.00	0.00	2.00	10.00	15.00	0.00	36.00	4.32	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	1632.00			Sealing Problem
Total waste		44.80	80.10	110.00	35.50	125.10	86.70	302.55	48.35	833.10		
Accept Products		3672	3480.00	3672.00	3456.00	3504.00	3504.00	3264.00	4008.00	28560.00		
Total		3716.80	3560.10	3782.00	3491.50	3629.10	3590.70	3566.55	4056.35	29393.10		
Line Efficiency %		98.8	97.8	97.1	99.0	96.6	97.6	91.5	98.8	97.2		
Waste %		1.2	2.2	2.9	1.0	3.4	2.4	8.5	1.2	2.8		
Total Process Waste = 113 ,13.56 % of waste												
Total Packing Waste = 786.1 , 94.4% of waste												
Dough waste = 5.64 % of waste												
Biscuit waste = 57.15 of Waste												
Biscuit with rubber waste = 37.21 of Waste												

Line 1B Waste Commissioning 9/2/06

stage	Area	1	2	3	4	5	6	7	8	Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnatic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Laminator	1.00	1.00	1.00	7.00	3.00	3.00	2.00	2.00	20.00	1.42	
	Press 1	1.00	1.00	1.00	4.00	3.00	2.00	0.00	2.00	14.00	0.99	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	2	0.00	560.00	0.00	1.00	5.00	2.00	1.00	571.00	40.53	Re-Start-up Bad appearance Shift A
conveyers	Slide	0	0.00	0.00	0.00	0.10	2.00	0.00	0.10	2.20	0.16	

	By-Pass	2.00	250.00	10.00	0.00	25.00	25.00	10.00	3.00	325.00	23.07	Cavana2 Finger problem in shift A
	Penny st. Guids1	0.50	0.10	0.00	2.00	0.00	0.00	0.00	0.00	2.60	0.18	
	Penny st. Guids2	0.50	0.10	0.00	0.10	0.10	0.50	0.10	0.10	1.50	0.11	
	Vibrator 1	0.00	0.00	0.00	0.00	0.20	0.00	0.10	0.00	0.30	0.02	
	Vibrator 2	0.00	0.00	0.00	0.00	0.22	0.00	0.10	0.32	0.64	0.05	
	Guide Bars Chine1	2.00	0.00	0.00	0.00	5.00	5.00	5.00	5.00	22.00	1.56	
	Guide Bars Chine2	2.00	0.00	0.00	5.00	5.00	5.00	3.00	5.00	25.00	1.77	
	Guide Convoyer1	0.1	0.50	0.00	0.00	0.00	1.00	1.00	2.00	4.60	0.33	
	Guide Convoyer2	0	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.10	0.01	
packing	Cavana 1	12.00	15.00	8.00	15.00	30.00	20.00	25.00	3.00	128.00	9.08	
	Cavana 2	15.00	35.00	5.00	10.00	30.00	20.00	25.00	2.00	142.00	10.08	Finger out of timing in 11:15 am shift A
	end seal 1	5.00	10.00	6.00	5.00	10.00	5.00	5.00	2.00	48.00	3.41	
	end seal 2	5.00	15.00	30.00	30.00	10.00	5.00	5.00	2.00	102.00	7.24	sealing problem in shift A
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total waste		48.10	327.70	621.10	78.10	122.62	98.50	83.30	29.52	1408.94		
Accept Products		3504	1080.00	3264.00	1716.00	3468.00	3468.00	3264.00	2839.20	22603.20		
Total		3552.10	1407.70	3885.10	1794.10	3590.62	3566.50	3347.30	2868.72	24012.14		
Line Efficiency %		98.6	76.7	84.0	95.6	96.6	97.2	97.5	99.0	94.1		
Waste %		1.4	23.3	16.0	4.4	3.4	2.8	2.5	1.0	5.9		
Total Process Waste = 605 ,42.9 % of waste												
Total Packing Waste = 803.94 , 75 % of waste												
Dough waste = 2.41 % of waste												
Biscuit waste = 67.78 of Waste												
Biscuit with wrapper waste = 29.81 of Waste												

Line 12 Waste (kg) Commissioning 11/2/06												
stage	Area	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnatic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Laminator	1.00	1.00	1.00	3.00	2.00	1.00	0.00	4.00	13.00	1.07	
	Press 1	1.00	2.00	0.00	0.00	2.00	0.00	0.00	1.00	6.00	0.49	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	49	2.00	1.00	75.00	35.00	3.00	1.00	2.00	168.00	13.78	Burnt biscuit
conveyers	Slide	0	0.00	1.00	0.00	1.00	0.00	0.00	0.00	2.00	0.16	
	By-Pass	26.00	30.00	13.00	20.00	30.00	15.00	62.00	10.00	206.00	16.90	Cavana1 problem in Shift A
	Penny st. Guids1	2.00	0.00	1.00	0.00	1.00	0.00	1.00	1.00	6.00	0.49	
	Penny st. Guids2	1.00	0.00	3.00	0.00	1.00	0.00	1.00	1.00	7.00	0.57	
	Vibrator 1	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	
	Vibrator 2	0.00	0.50	0.00	0.50	0.00	0.00	1.00	0.00	2.00	0.16	
	Guide Bars Chine1	7.00	8.00	3.00	5.00	10.00	15.00	5.00	2.00	55.00	4.51	
	Guide Bars Chine2	2.00	5.00	2.00	8.00	9.00	15.00	1.00	2.00	44.00	3.61	
	Guide Convoyer1	8	5.00	2.00	8.00	3.00	5.00	5.00	2.00	38.00	3.12	
	Guide Convoyer2	0.1	0.00	1.00	2.00	0.00	0.00	0.00	0.00	3.10	0.25	
packing	Cavana 1	64.00	30.00	25.00	28.00	15.00	20.00	21.00	10.00	213.00	17.47	Biscuit broken in shift A
	Cavana 2	45.00	35.00	30.00	35.00	10.00	20.00	22.00	15.00	212.00	17.39	
	end seal 1	10.00	18.00	10.00	20.00	8.00	10.00	11.00	10.00	97.00	7.96	

	end seal 2	7.00	20.00	40.00	40.00	8.00	10.00	12.00	10.00	147.00	12.06	Cooder problem(packets without date)
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Total waste		223.10	156.60	133.00	244.50	135.00	114.00	143.00	70.00	1219.20		
Accept Products		2424	3672.00	3672.00	3288.00	2760.00	3060.00	3060.00	5160.00	27096.00		
Total		2647.10	3828.60	3805.00	3532.50	2895.00	3174.00	3203.00	5230.00	28315.20		
Line Efficiency %		91.6	95.9	96.5	93.1	95.3	96.4	95.5	98.7	95.7		
Waste %		8.4	4.1	3.5	6.9	4.7	3.6	4.5	1.3	4.3		
Total Process Waste = 187 kg ,15.34 % Total of waste												
Total Packing Waste = 1032.2 kg , 84.6 % of Total waste												
Dough waste = 1.56% of Total waste												
Biscuit waste = 43.57 of Total Waste												
Biscuit with wrapper waste = 54.87 of Total Waste												

Line 12 Waste (kg) Commissioning 12/2/06

Process	Activities	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	2.00	1.00	2.00	0.00	0.00	8.00	0.65	
	Press 1	1.00	1.00	0.00	1.00	1.00	2.00	3.00	1.00	10.00	0.81	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	210	0.00	0.00	2.00	1.00	2.00	1.00	2.00	218.00	17.70	Bad appearance(Cutting problem) 17 min 2 sec
Cooling	Slide	1	2.00	0.00	0.00	2.00	0.00	0.00	0.00	5.00	0.41	

	By-Pass	75.00	35.00	0.00	0.00	45.00	45.00	10.00	35.00	245.00	19.89	Products taken off line due to broken biscuits problem in shift B 22 min 30 sec
	Penny st. Guids1	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.50	0.12	
	Penny st. Guids2	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.08	
Aligning	Vibrator 1	0.10	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.10	0.09	
	Vibrator 2	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.08	
	Guide Bars Chine1	5.00	4.00	2.00	0.00	10.00	20.00	10.00	15.00	66.00	5.36	
	Guide Bars Chine2	6.00	5.00	3.00	0.00	5.00	20.00	9.00	10.00	58.00	4.71	
	Guide Conveyer1	0.1	0.50	0.10	0.00	5.00	10.00	8.00	10.00	33.70	2.74	
	Guide Conveyer2	0	0.00	0.50	0.00	0.00	0.00	5.00	0.00	5.50	0.45	
Packing1	Cavana 1	12.00	20.00	7.00	15.00	40.00	40.00	30.00	75.00	239.00	19.40	Broken biscuits problems shift B 15 min 25 sec
Packing2	Cavana 2	15.00	25.00	15.00	16.00	15.00	45.00	25.00	75.00	231.00	18.75	Broken biscuits problems shift B 18 min 20 sec
Packaging1	end seal 1	4.00	0.00	3.00	2.00	10.00	5.00	5.00	10.00	39.00	3.17	
Packaging2	end seal 2	14.00	10.00	10.00	5.00	10.00	5.00	5.00	10.00	69.00	5.60	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total waste		344.70	103.50	41.60	43.00	149.00	196.00	111.00	243.00	1231.80		
Accept Products		3096	3672.00	3672.00	3264.00	3264.00	3264.00	3264.00	4488.00	27984.00		
Total		3440.70	3775.50	3713.60	3307.00	3413.00	3460.00	3375.00	4731.00	29215.80		
Line Efficiency %		90.0	97.3	98.9	98.7	95.6	94.3	96.7	94.9	95.8		
Waste %		10.0	2.7	1.1	1.3	4.4	5.7	3.3	5.1	4.2		
Total Process Waste = 236 kg ,19.15 % of Total waste												
Total Packing Waste = 995.8 kg , 80.84% of Total waste												
Dough waste = 1.46 % of Total waste												
Biscuit waste = 51.62 of Total Waste												
Biscuit with wrapper waste = 46.92 of Total Waste												

Line 12 Waste (kg) Commissioning 13/2/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	3.00	1.00	2.00	1.00	1.00	11.00	1.09	
	Press 1	1.00	0.00	1.00	1.00	1.00	0.00	3.00	1.00	8.00	0.79	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	5	90.00	100.00	2.00	1.00	1.00	1.00	1.00	201.00	19.93	burnt biscuit shift A\Bad appearance(Cutting problem) Shift B 25 min 12 sec
Cooling	Slide	0	0.10	0.00	0.00	0.00	0.00	1.00	0.00	1.10	0.11	
	By-Pass	20.00	30.00	0.00	0.00	20.00	2.00	45.00	15.00	132.00	13.09	Products taken off line due to broken biscuits problem 18 min 40 sec
	Penny st. Guids1	3.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	4.00	0.40	
	Penny st. Guids2	2.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00	0.30	
Aligning	Vibrator 1	1.00	0.00	0.00	1.00	2.00	0.00	0.00	0.00	4.00	0.40	
	Vibrator 2	0.00	0.00	0.00	1.00	2.00	0.00	0.00	0.00	3.00	0.30	
	Guide Bars Chine1	4.00	3.00	2.00	2.00	8.00	0.00	10.00	10.00	39.00	3.87	
	Guide Bars Chine2	2.00	5.00	3.00	1.00	8.00	0.00	10.00	5.00	34.00	3.37	
	Guide Conveyer1	1	1.00	0.00	1.00	5.00	5.00	5.00	10.00	28.00	2.78	
	Guide Conveyer2	0.05	0.50	0.00	0.00	2.00	3.00	0.00	3.00	8.55	0.85	
Packing1	Cavana 1	15.00	15.00	10.00	15.00	45.00	15.00	45.00	60.00	220.00	21.81	Broken biscuits problems 17 min 2 sec
Packing2	Cavana 2	8.00	15.00	8.00	16.00	30.00	15.00	20.00	60.00	172.00	17.05	Broken biscuits problems 16 min 30 sec
Packaging1	end seal 1	5.00	10.00	5.00	8.00	20.00	2.00	5.00	10.00	65.00	6.44	

Packaging2	end seal 2	8.00	15.00	10.00	5.00	20.00	2.00	5.00	10.00	75.00	7.44	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total waste		76.05	185.60	140.00	56.00	167.00	47.00	151.00	186.00	1008.65		
Accept Products		3672	3432	2976	2976	3672	3672	2448	5076	27924		
Total		3748.05	3617.60	3116.00	3032.00	3839.00	3719.00	2599.00	5262.00	28932.65		
Line Efficiency %		98.0	94.9	95.5	98.2	95.6	98.7	94.2	96.5	96.5		
Waste %		2.0	5.1	4.5	1.8	4.4	1.3	5.8	3.5	3.5		
Total Process Waste = 220 kg ,21.8 % of Total waste												
Total Packing Waste = 788.65 kg , 78.2 % of Total waste												
Dough waste = 1.88% of Total waste												
Biscuit waste = 45.37 of Total Waste												
Biscuit with wrapper waste = 52.74 of Total Waste												

Line 12 Waste(kg) Commissioning 14/2/06

Process	Activity	Time								Total	Waste %	Comment
		7-11:15am	11:55-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	2.00	1.00	1.00	2.00	1.00	2.00	2.00	1.00	12.00	1.70	
	Press 1	1.00	1.00	0.00	1.00	2.00	1.00	0.00	1.00	7.00	0.99	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	2	90.00	15.00	2.00	1.00	1.00	1.00	1.00	113.00	16.03	RE-start-up shift A\Cutting Problem shift B 15 min 20 sec
Cooling	Slide	0	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.14	
	By-Pass	10.00	15.00	10.00	0.00	1.00	5.00	0.00	10.00	51.00	7.23	
	Penny st. Guids1	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.14	

	Penny st. Guids2	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.14	
Aligning	Vibrator 1	4.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	6.00	0.85	
	Vibrator 2	6.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	8.00	1.13	
	Guide Bars Chine1	8.00	0.00	7.00	10.00	3.00	4.00	0.00	0.00	32.00	4.54	
	Guide Bars Chine2	4.00	0.00	8.00	20.00	3.00	3.00	0.00	0.00	38.00	5.39	
	Guide Conveyer1	3	0.00	0.00	1.00	2.00	0.00	6.00	5.00	17.00	2.41	
	Guide Conveyer2	4	0.00	0.00	3.00	1.00	0.00	0.00	5.00	13.00	1.84	
Packing1	Cavana 1	14.00	14.00	12.00	20.00	15.00	15.00	3.00	15.00	108.00	15.32	Broken biscuit 18 min 36 sec
Packing2	Cavana 2	14.00	28.00	28.00	35.00	10.00	15.00	2.00	10.00	142.00	20.14	Broken biscuit 17 min 22 sec
Packaging1	end seal 1	10.00	18.00	0.00	10.00	5.00	5.00	3.00	5.00	56.00	7.94	
Packaging2	end seal 2	10.00	22.00	20.00	30.00	5.00	5.00	2.00	5.00	99.00	14.04	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total waste		92.00	189.00	101.00	134.00	56.00	56.00	19.00	58.00	705.00		
Accept Products		5263.2	2144.0	2960.0	2960.0	3712.0	3856.0	3648.0	3760.0	28303.2		
Total		5355.20	2333.00	3061.00	3094.00	3768.00	3912.00	3667.00	3818.00	29008.20		
Line Efficiency %		98.3	91.9	96.7	95.7	98.5	98.6	99.5	98.5	97.6		
Waste %		1.7	8.1	3.3	4.3	1.5	1.4	0.5	1.5	2.4		
Total Process Waste = 132 kg ,18.7 % of Total waste												
Total Packing Waste = 573 kg , 81.3 % of Total waste												
Dough waste = 2.7% of Total waste												
Biscuit waste = 39.86 of Total Waste												
Biscuit with wrapper waste = 57.45 of Total Waste												

Line 12 Waste (kg) Commissioning 15/2/06												
Process	Activity	Time								Total	Waste %	Comment
		7-11:15am	11:55-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	4.00	1.00	2.00	1.00	4.00	15.00	0.73	
	Press 1	1.00	0.00	1.00	0.00	1.00	1.00	1.00	1.00	6.00	0.29	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	3	45.00	30.00	43.00	15.00	6.00	3.00	11.00	156.00	7.55	Bad Appearance (Cutting Problem) 16 min 44 sec
Cooling	Slide	1	0.00	1.00	0.00	2.00	0.00	0.00	0.00	4.00	0.19	
	By-Pass	40.00	80.00	30.00	50.00	125.00	150.00	50.00	150.00	675.00	32.67	Program stopped in cavana 1 Shift A 15 min 55 sec
	Penny st. Guids1	2.00	0.00	1.00	0.00	2.00	0.00	0.00	0.00	5.00	0.24	
	Penny st. Guids2	2.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	4.00	0.19	
Aligining	Vibrator 1	0.00	4.00	0.00	0.00	1.00	0.00	0.00	0.00	5.00	0.24	
	Vibrator 2	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.29	
	Guide Bars Chine1	3.00	10.00	2.00	5.00	15.00	15.00	10.00	0.00	60.00	2.90	
	Guide Bars Chine2	4.00	25.00	10.00	8.00	15.00	15.00	10.00	0.00	87.00	4.21	
	Guide Conveyer1	0.1	2.00	1.00	0.00	15.00	15.00	25.00	10.00	68.10	3.30	
	Guide Conveyer2	8	15.00	5.00	0.00	10.00	15.00	0.00	25.00	78.00	3.78	
Packing1	Cavana 1	15.00	50.00	20.00	2.00	50.00	50.00	50.00	25.00	262.00	12.68	Program stopped Sh A\Broken biscuit (Loader Problem) 15 min 13 sec
Packing2	Cavana 2	45.00	60.00	30.00	35.00	50.00	50.00	55.00	25.00	350.00	16.94	Broken biscuit (Loader Problem) 20 min 20 sec

Packaging1	end seal 1	10.00	20.00	10.00	8.00	50.00	0.00	0.00	10.00	108.00	5.23	
Packaging2	end seal 2	20.00	50.00	20.00	22.00	50.00	0.00	0.00	15.00	177.00	8.57	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total waste		155.10	368.00	163.00	177.00	403.00	319.00	205.00	276.00	2066.10		
Accept Products		2400.0	2148.0	2496.0	3036.0	3468.0	3468.0	2912.0	2912.0	22840.0		
Total		2555.10	2516.00	2659.00	3213.00	3871.00	3787.00	3117.00	3188.00	24906.10		
Line Efficiency %		93.9	85.4	93.9	94.5	89.6	91.6	93.4	91.3	91.7		
Waste %		6.1	14.6	6.1	5.5	10.4	8.4	6.6	8.7	8.3		
Total Process Waste = 132 kg ,18.7 % of Total waste												
Total Packing Waste = 573 kg , 81.3 % of Total waste												
Dough waste = 2.7% of Total waste												
Biscuit waste = 39.86 of Total Waste												
Biscuit with wrapper waste = 57.45 of Total Waste												

Line 12 Waste (kg) Commissioning 16/2/06

Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	3.00	1.00	2.00	1.00	1.00	11.00	0.74	
	Press 1	1.00	1.00	0.00	0.00	1.00	0.00	1.00	1.00	5.00	0.34	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	15	14.00	12.00	85.00	1.00	0.00	1.00	1.00	129.00	8.66	Bad Appearance (Cutting Problem) 23 min 40 sec
Cooling	Slide	0	1.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00	0.13	
	By-Pass	0.00	20.00	10.00	0.10	410.00	0.00	10.00	10.00	460.10	30.88	Problem in cavana 1 Shift A\Problem in Cavana 1,2 Shift B 25 min 20 sec

	Penny st. Guids1	0.00	1.00	0.00	0.00	2.00	0.00	0.00	0.00	3.00	0.20	
	Penny st. Guids2	0.00	3.00	0.00	0.00	2.00	0.00	0.00	0.00	5.00	0.34	
Aligning	Vibrator 1	0.00	2.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00	0.20	
	Vibrator 2	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00	0.13	
	Guide Bars Chine1	0.00	0.00	1.00	0.00	3.00	0.00	0.00	0.00	4.00	0.27	
	Guide Bars Chine2	12.00	15.00	10.00	5.00	3.00	0.00	0.00	0.00	45.00	3.02	
	Guide Conveyer1	0.1	0.10	0.00	0.80	10.00	0.00	0.00	3.00	14.00	0.94	
	Guide Conveyer2	4	10.00	5.00	10.00	20.00	0.00	0.00	3.00	52.00	3.49	
Packing1	Cavana 1	15.00	25.00	20.00	20.00	45.00	5.00	15.00	15.00	160.00	10.74	Law Air Pressure Shift B 15 min 20 sec
Packing2	Cavana 2	35.00	65.00	45.00	60.00	50.00	5.00	15.00	15.00	290.00	19.46	Exit Belt Broken Shift A\ Law Air Pressure Shift B 23 min 10 sec
Packaging1	end seal 1	13.00	20.00	15.00	20.00	30.00	0.00	0.00	3.00	101.00	6.78	
Packaging2	end seal 2	25.00	50.00	40.00	50.00	28.00	6.00	2.00	3.00	204.00	13.69	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	285.60	285.60		High Moisture (4.68%) - Normal 3% Shift B 24 min 10 sec
Total waste		121.10	229.10	159.00	253.90	609.00	18.00	45.00	55.00	1490.10		
Accept Products		3672.0	3600.0	3072.0	1896.0	1360.0	3468.0	3468.0	4202.4	24738.4		
Total		3793.10	3829.10	3231.00	2149.90	1969.00	3486.00	3513.00	4257.40	26228.50		
Line Efficiency %		96.8	94.0	95.1	88.2	69.1	99.5	98.7	98.7	94.3		
Waste %		3.2	6.0	4.9	11.8	30.9	0.5	1.3	1.3	5.7		
Total Process Waste = 145 kg ,9.73 % of Total waste												
Total Packing Waste =1345.1kg , 90.3 % of Total waste												
Dough waste = 1.07% of Total waste												
Biscuit waste = 48.26 of Total Waste												
Biscuit with wrapper waste = 50.67 of Total Waste												

Line 12 Waste (kg) Commissioning 18/2/06												
Process	Activities	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	9.00	0.59	
	Press 1	1.00	1.00	1.00	0.00	1.00	1.00	2.00	2.00	9.00	0.59	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	130	28.00	75.00	2.00	0.00	1.00	0.00	1.00	237.00	15.50	Bad Appearance (Cutting Problem) 19 min 25 sec
Cooling	Slide	0	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.07	
	By-Pass	300.00	260.00	10.00	0.00	30.00	0.00	20.00	20.00	640.00	41.86	Adjustment of VBF Loader 2 times Shift A 25 min 12 sec
	Penny st. Guids1	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.33	
	Penny st. Guids2	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.33	
Aligning	Vibrator 1	2.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	3.00	0.20	
	Vibrator 2	5.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	7.00	0.46	
	Guide Bars Chine1	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.13	
	Guide Bars Chine2	30.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00	50.00	3.27	
	Guide Conveyer1	0	1.00	0.00	0.00	5.00	0.00	5.00	0.00	11.00	0.72	
	Guide Conveyer2	10	5.00	2.00	0.00	5.00	0.00	5.00	1.00	28.00	1.83	
Packing1	Cavana 1	25.00	0.00	12.00	10.00	23.00	10.00	15.00	10.00	105.00	6.87	Broken Biscuits Shift A 18 min 20 sec
Packing2	Cavana 2	80.00	50.00	35.00	10.00	22.00	15.00	15.00	11.00	238.00	15.57	Broken Biscuits Shift A 16 min 30 sec
Packaging1	end seal 1	20.00	10.00	5.00	0.00	5.00	0.00	0.00	2.00	42.00	2.75	

Packaging2	end seal 2	70.00	30.00	30.00	0.00	4.00	0.00	0.00	3.00	137.00	8.96	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total waste		684.00	398.00	182.00	24.00	99.00	28.00	63.00	51.00	1529.00		
Accept Products		1464.0	2064.0	3324.0	3405.6	3672.0	3672.0	2448.0	5124.0	25173.6		
Total		2148.00	2462.00	3506.00	3429.60	3771.00	3700.00	2511.00	5175.00	26702.60		
Line Efficiency %		68.2	83.8	94.8	99.3	97.4	99.2	97.5	99.0	94.3		
Waste %		31.8	16.2	5.2	0.7	2.6	0.8	2.5	1.0	5.7		
Total Process Waste = 255 kg ,16.7% of Total waste												
Total Packing Waste =1274 kg ,83.3 % of Total waste												
Dough waste = 1.18% of Total waste												
Biscuit waste = 64.68 % of Total Waste												
Biscuit with wrapper waste = 34.14 % of Total Waste												

Line 12 Waste (kg) Commissioning 19/2/06

Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	1.00	2.00	1.00	1.00	2.00	2.00	11.00	1.31	
	Press 1	1.00	1.00	0.00	1.00	0.00	1.00	2.00	1.00	7.00	0.83	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	2	0.50	210.00	0.00	11.00	3.00	3.00	4.00	233.50	27.84	Break down cooling conveyor shift A\Bad Appearance shift B 14 min 20 sec
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	0.00	0.00	0.00	20.00	42.00	60.00	0.00	0.00	122.00	14.54	S.B.F Loader 2 Problem shift B 14 min 10 sec
	Penny st. Guids1	0.00	1.00	0.00	0.00	1.00	1.00	0.00	0.00	3.00	0.36	

	Penny st. Guids2	0.00	1.00	0.00	0.00	2.00	1.00	0.00	0.00	4.00	0.48	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.12	
	Vibrator 2	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.12	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	3.00	5.00	0.00	0.00	8.00	0.95	
	Guide Bars Chine2	0.00	3.00	5.00	5.00	5.00	5.00	0.00	0.00	23.00	2.74	
	Guide Conveyer1	0.1	0.50	0.00	0.50	1.00	5.00	0.00	0.00	7.10	0.85	
	Guide Conveyer2	0.2	3.00	0.00	2.00	2.00	5.00	2.00	0.00	14.20	1.69	
Packing1	Cavana 1	12.00	5.00	10.00	10.00	32.00	20.00	10.00	10.00	109.00	12.99	Broken Biscuits 25 min 17 sec
Packing2	Cavana 2	25.00	20.00	20.00	35.00	35.00	20.00	10.00	10.00	175.00	20.86	Broken Biscuits 16 min 20 sec
Packaging1	end seal 1	0.00	6.00	0.00	10.00	5.00	5.00	2.00	0.00	28.00	3.34	
Packaging2	end seal 2	20.00	10.00	10.00	40.00	5.00	5.00	2.00	0.00	92.00	10.97	
On Hold		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Total waste		61.30	52.00	256.00	125.50	147.00	137.00	33.00	27.00	838.80		
Accept Products		3672.0	3840.0	3600.0	2760.0	3876.0	3876.0	3652.0	4284.0	29560.0		
Total		3733.30	3892.00	3856.00	2885.50	4023.00	4013.00	3685.00	4311.00	30398.80		
Line Efficiency %		98.4	98.7	93.4	95.7	96.3	96.6	99.1	99.4	97.2		
Waste %		1.6	1.3	6.6	4.3	3.7	3.4	0.9	0.6	2.8		
Total Process Waste = 251.5 kg ,30% of Total waste												
Total Packing Waste =587.3 kg ,70 % of Total waste												
Dough waste = 2.15 % of Total waste												
Biscuit waste = 49.69 % of Total Waste												
Biscuit with wrapper waste = 48.16 % of Total Waste												

Line 12 Waste (kg) Commissioning 20/2/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.43	
Laminating	Laminator	1.00	1.00	1.00	2.00	1.00	1.00	0.00	2.00	9.00	1.95	
	Press 1	1.00	0.00	0.00	1.00	1.00	1.00	0.00	1.00	5.00	1.08	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	1	2.00	4.00	1.00	0.50	1.00	1.00	1.00	11.50	2.49	
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	40.00	10.00	50.00	10.81	
	By-Pass	0.00	20.00	20.00	20.00	0.00	0.00	0.00	0.00	60.00	12.97	Problem in Cavana 2. 8 min 30 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.22	
	Guide Bars Chine2	0.00	2.00	3.00	0.00	1.00	0.00	0.00	5.00	11.00	2.38	
	Guide Conveyer1	0.2	0.50	0.50	0.00	0.00	3.00	5.00	5.00	14.20	3.07	
	Guide Conveyer2	0.5	0.50	1.00	0.00	0.00	3.00	5.00	0.00	10.00	2.16	
Packing1	Cavana 1	12.00	12.00	12.00	0.00	10.00	10.00	15.00	10.00	81.00	17.51	Broken Biscuits 5 min 30 sec
Packing2	Cavana 2	12.00	20.00	20.00	10.00	15.00	10.00	15.00	10.00	112.00	24.21	Broken Biscuits 3 min 20 sec
Packaging1	end seal 1	0.00	8.00	8.00	5.00	2.00	3.00	10.00	5.00	41.00	8.86	

Packaging2	end seal 2	10.00	10.00	10.00	5.00	2.00	3.00	10.00	5.00	55.00	11.89	
On Hold										0.00		
Total waste		37.70	76.00	79.50	44.00	35.50	35.00	101.00	54.00	462.70		
Accept Products		3672.0	3720.0	3672.0	3804.0	3876.0	3672.0	2652.0	5124.0	30192.0		
Total		3709.70	3796.00	3751.50	3848.00	3911.50	3707.00	2753.00	5178.00	30654.70		
Line Efficiency %		99.0	98.0	97.9	98.9	99.1	99.1	96.3	99.0	98.5		
Waste %		1.0	2.0	2.1	1.1	0.9	0.9	3.7	1.0	1.5		
Total Process Waste = 251.5 kg ,30% of Total waste												
Total Packing Waste =587.3 kg ,70 % of Total waste												
Dough waste = 2.15 % of Total waste												
Biscuit waste = 49.69 % of Total Waste												
Biscuit with wrapper waste = 48.16 % of Total Waste												

Line 12 Waste(kg) Commissioning 21/2/06

Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.52	
Laminating	Laminator	1.00	1.00	1.00	2.00	1.00	1.00	2.00	2.00	11.00	1.90	
	Press 1	1.00	0.00	0.00	1.00	1.00	1.00	1.00	0.00	5.00	0.86	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	4	12.00	25.00	2.00	1.00	0.50	0.50	3.00	48.00	8.27	
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	20.00	15.00	0.00	10.00	40.00	10.00	10.00	10.00	115.00	19.82	Problem in Cavana 26 min 20 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	5.00	0.86	
	Vibrator 2	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	5.00	0.86	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	10.00	0.00	10.00	0.00	20.00	3.45	
	Guide Bars Chine2	0.00	2.00	0.00	0.60	15.00	5.00	10.00	0.00	32.60	5.62	
	Guide Conveyer1	0	0.10	0.00	0.40	2.00	5.00	5.00	0.00	12.50	2.15	
	Guide Conveyer2	0	0.10	0.00	3.00	3.00	5.00	5.00	0.00	16.10	2.77	
Packing1	Cavana 1	12.00	10.00	5.00	10.00	35.00	10.00	10.00	5.00	97.00	16.72	Broken Biscuits 22 min 45 sec
Packing2	Cavana 2	14.00	15.00	10.00	20.00	35.00	10.00	10.00	5.00	119.00	20.51	Broken Biscuits 23 min 38 sec
Packaging1	end seal 1	7.00	5.00	0.00	9.00	10.00	5.00	2.00	2.00	40.00	6.89	
Packaging2	end seal 2	5.00	10.00	5.00	10.00	12.00	5.00	2.00	2.00	51.00	8.79	
On Hold										0.00		
Total waste		67.00	70.20	46.00	68.00	175.00	57.50	67.50	29.00	580.20		
Accept Products		3672.0	3672.0	3600.0	2520.0	3672.0	3876.0	2448.0	5100.0	28560.0		
Total		3739.00	3742.20	3646.00	2588.00	3847.00	3933.50	2515.50	5129.00	29140.20		
Line Efficiency %		98.2	98.1	98.7	97.4	95.5	98.5	97.3	99.4	98.0		
Waste %		1.8	1.9	1.3	2.6	4.5	1.5	2.7	0.6	2.0		
Total Process Waste = 67 kg ,11.55% of Total waste												
Total Packing Waste =513 kg ,88.5 % of Total waste												
Dough waste = 3.27% of Total waste												
Biscuit waste = 43.81 % of Total Waste												
Biscuit with wrapper waste = 52.91 % of Total Waste												

Line 12 Waste (kg) Commissioning 22/2/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.28	
Laminating	Laminator	1.00	1.00	1.00	2.00	1.00	1.00	1.00	1.00	9.00	2.53	
	Press 1	1.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	3.00	0.84	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	1	2.00	11.00	3.00	2.00	1.00	0.50	1.00	21.50	6.04	
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	0.00	0.00	0.00	0.00	20.00	10.00	10.00	10.00	50.00	14.04	Problem in Cavana 25 min 30 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	1.00	0.00	0.00	0.00	0.00	0.00	2.00	3.00	0.84	
	Vibrator 2	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.28	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	2.00	1.00	2.00	2.00	7.00	1.97	
	Guide Bars Chine2	0.00	2.00	0.00	0.00	2.00	1.00	2.00	2.00	9.00	2.53	
	Guide Conveyer1	0	0.10	0.40	0.00	0.00	0.00	0.00	1.00	1.50	0.42	
	Guide Conveyer2	0	0.50	0.50	0.00	0.00	1.00	0.00	1.00	3.00	0.84	
Packing1	Cavana 1	12.00	10.00	12.00	10.00	15.00	10.00	10.00	5.00	84.00	23.60	Broken Biscuits 23 min 10 sec
Packing2	Cavana 2	13.00	15.00	15.00	16.00	15.00	10.00	10.00	5.00	99.00	27.81	Broken Biscuits 22 min 40 sec
Packaging1	end seal 1	3.00	5.00	10.00	0.00	5.00	2.00	0.00	0.00	25.00	7.02	
Packaging2	end seal 2	5.00	8.00	13.00	6.00	5.00	2.00	0.00	0.00	39.00	10.96	
Scrap		3.00	4.00	3.00	1.00	9.00	8.00	7.00	12.50	47.50		
Total waste		39.00	49.60	65.90	38.00	77.00	48.00	42.50	43.50	356.00		
Accept Products		3600.0	3672.0	3720.0	3528.0	3360.0	3264.0	2808.0	4488.0	28440.0		
Total		3639.00	3721.60	3785.90	3566.00	3437.00	3312.00	2850.50	4531.50	28796.00		

Line Efficiency %	98.9	98.7	98.3	98.9	97.8	98.6	98.5	99.0	98.8		
Waste %	1.1	1.3	1.7	1.1	2.2	1.4	1.5	1.0	1.2		
Total Process Waste = 34.5 kg ,9.7% of Total waste											
Total Packing Waste =321.5 kg ,90.3 % of Total waste											
Dough waste = 3.65% of Total waste											
Biscuit waste = 26.97% of Total Waste											
Biscuit with wrapper waste = 69.38 % of Total Waste											

Line 12 Waste (kg) Commissioning 23/2/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.31	
Laminatin g	Laminator	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	8.00	2.49	
	Press 1	0.00	0.00	0.00	0.00	1.00	0.00	1.00	1.00	3.00	0.93	
	Press 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	3	2.00	3.00	9.00	1.00	0.50	0.50	3.00	22.00	6.84	
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00	20.00	6.22	
	Penny st. Guids1	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.31	
	Penny st. Guids2	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.62	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.31	
	Guide Bars Chine2	0.00	3.00	0.00	0.00	1.00	0.00	0.00	0.00	4.00	1.24	
	Guide Conveyer1	0	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.62	
	Guide Conveyer2	0	0.50	0.00	0.00	2.00	0.00	0.00	0.00	2.50	0.78	
Packing1	Cavana 1	12.00	10.00	0.00	0.00	10.00	12.00	10.00	10.00	64.00	19.91	Broken Biscuits 15 min 20 sec
Packing2	Cavana 2	12.00	15.00	10.00	10.00	11.00	11.00	10.00	12.00	91.00	28.30	Broken Biscuits 16 min 30 sec

Packaging1	end seal 1	0.00	5.00	9.00	9.00	2.00	10.00	5.00	12.00	52.00	16.17	
Packaging2	end seal 2	10.00	5.00	7.00	7.00	2.00	5.00	2.00	10.00	48.00	14.93	
Scrap		3.00	5.00	9.00	2.00	2.50	10.00	6.00	12.00	49.50		
Total waste		41.00	49.50	39.00	38.00	37.50	49.50	35.50	81.00	321.50		
Accept Products		3672.0	3720.0	4032.0	3960.0	3912.0	4080.0	2448.0	4605.6	30429.6		
Total		3713.00	3769.50	4071.00	3998.00	3949.50	4129.50	2483.50	4686.60	30751.10		
Line Efficiency %		98.9	98.7	99.0	99.0	99.1	98.8	98.6	98.3	99.0		
Waste %		1.1	1.3	1.0	1.0	0.9	1.2	1.4	1.7	1.0		
Total Process Waste = 34.5 kg ,9.7% of Total waste												
Total Packing Waste =321.5 kg ,90.3 % of Total waste												
Dough waste = 3.65% of Total waste												
Biscuit waste = 26.97% of Total Waste												
Biscuit with wrapper waste = 69.38 % of Total Waste												

Line 12 Waste (kg) Commissioning 28/2/06

Process	Activity	Time			Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm			
Mixing	Magnetic detector	2.00	0.00	0.00	2.00	0.55	
Laminating	Laminator	1.00	0.00	1.00	2.00	0.55	
	Press 1	1.00	1.00	1.00	3.00	0.82	
	Press 2	0.00	0.00	0.00	0.00	0.00	
	Press 3	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	90	2.00	1.00	93.00	25.55	
Cooling	Slide	4	3.00	5.00	12.00	3.30	Out of Lining waste 25 min 20 sec
	By-Pass	0.00	20.00	0.00	20.00	5.49	
	Penny st. Guids1	2.00	0.00	0.00	2.00	0.55	
	Penny st. Guids2	4.00	0.00	0.00	4.00	1.10	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	

	Guide Bars Chine1	0.00	5.00	0.00	5.00	1.37	
	Guide Bars Chine2	3.00	10.00	0.00	13.00	3.57	
	Guide Conveyer1	0	0.00	1.00	1.00	0.27	
	Guide Conveyer2	0	0.00	2.00	2.00	0.55	
Packing1	Cavana 1	13.00	30.00	10.00	53.00	14.56	Broken Biscuits 8 min 20 sec
Packing2	Cavana 2	15.00	35.00	15.00	65.00	17.86	Broken Biscuits 19 min 15 sec
Packaging1	end seal 1	10.00	10.00	5.00	25.00	6.87	
Packaging2	end seal 2	12.00	40.00	10.00	62.00	17.03	
Scrap		5.00	5.00	3.00	13.00		
Total waste		162.00	161.00	54.00	364.00		
Accept Products		3672.0	3720.0	4032.0	11424.0		
Total		3834.00	3881.00	4086.00	11788.00		
Line Efficiency %		95.8	95.9	98.7	96.9		
Waste %		4.2	4.1	1.3	3.1		
Total Process Waste = 34.5 kg ,9.7% of Total waste							
Total Packing Waste =321.5 kg ,90.3 % of Total waste							
Dough waste = 3.65% of Total waste							
Biscuit waste = 26.97% of Total Waste							
Biscuit with wrapper waste = 69.38 % of Total Waste							

Line 12 Waste (kg) Commissioning 1/3/06

Process	Activity	Morning coffee	Super Mari	Total	Waste %	Comment
		7-10 am	1-3 pm			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	2.00	3.00	0.24	
	Press 1	0.00	0.00	0.00	0.00	
	Press 2	1.00	2.00	3.00	0.24	
	Press 3	0.00	0.00	0.00	0.00	

Oven	After oven	30	320.00	350.00	27.54	
Cooling	Slide	0	10.00	10.00	0.79	
	By-Pass	150.00	300.00	450.00	35.41	
	Penny st. Guids1	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	10.00	10.00	0.79	
	Vibrator 2	0.00	15.00	15.00	1.18	
	Guide Bars Chine1	15.00	20.00	35.00	2.75	
	Guide Bars Chine2	20.00	22.00	42.00	3.30	
	Guide Conveyer1	5	5.00	10.00	0.79	
	Guide Conveyer2	6	7.00	13.00	1.02	
Packing1	Cavana 1	80.00	0.00	80.00	6.29	
Packing2	Cavana 2	150.00	100.00	250.00	19.67	
Packaging1	end seal 1	0.00	0.00	0.00	0.00	
Packaging2	end seal 2	0.00	0.00	0.00	0.00	
Scrap		15.00	12.00	27.00		
Total waste		473.00	825.00	1271.00		
Accept Products		0.0	0.0	0.0		
Total		473.00	825.00	1271.00		
Line Efficiency %		0.0	0.0	0.0		
Waste %		100.0	100.0	100.0		
Total Process Waste = 356 kg ,28% of Total waste						
Total Packing Waste =942 kg ,74.12 % of Total waste						
Dough waste = 0.47 % of Total waste						
Biscuit waste = 73.56 % of Total Waste						
Biscuit with wrapper waste = 25.96 % of Total Waste						

Line 12 Waste (kg) Commissioning 8/3/06

Process	Activity	Time 10-1 pm	Time 1-3 pm	Time 3-6 pm	Total	Waste %	Comment
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	2.00	1.00	1.00	4.00	0.26	
	Press 1	0.00	0.00	0.00	0.00	0.00	
	Press 2	1.00	1.00	0.00	2.00	0.13	
	Press 3	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	210.00	75.00	20.00	305.00	19.75	Start up Broken Biscuit 14 min 2 sec
Cooling	Slide	0.00	0.00	0.00	0.00	0.00	
	By-Pass	150.00	156.00	50.00	356.00	23.06	Gap from 9:30 to 10:30 am seal polder problem 60 min 4 sec
	Penny st. Guids1	2.00	1.00	0.00	3.00	0.19	
	Penny st. Guids2	1.00	1.00	0.00	2.00	0.13	
Aligning	Vibrator 1	2.00	2.00	0.00	4.00	0.26	
	Vibrator 2	3.00	3.00	0.00	6.00	0.39	
	Guide Bars Chine1	4.00	5.00	0.00	9.00	0.58	
	Guide Bars Chine2	1.00	0.00	0.00	1.00	0.06	
	Guide Conveyer1	1.00	5.00	0.00	6.00	0.39	
	Guide Conveyer2	2.00	2.00	0.00	4.00	0.26	
packing	Cavana 1	100.00	51.00	100.00	251.00	16.26	Sealing Problem 60 min 5 sec
	Cavana 2	110.00	56.00	100.00	266.00	17.23	
	end seal 1	105.00	25.00	20.00	150.00	9.72	
	end seal 2	120.00	25.00	30.00	175.00	11.33	
Scrap		6.00	3.50	6.00	15.50		
Total waste		820.00	412.50	327.00	1544.00		
Accept Products		2244.0	1463.0	2244.0	5951.0		
Total		3064.00	1875.50	2571.00	7495.00		
Line Efficiency %		73.2	78.0	87.3	79.4		
Waste %		26.8	22.0	12.7	20.6		
Total Process Waste = 311 kg ,20.14% of Total waste							

Total Packing Waste =1248.5kg ,80.86 % of Total waste	
Dough waste = 0.39 % of Total waste	
Biscuit waste =45.08 % of Total Waste	
Biscuit with wrapper waste = 54.53 % of Total Waste	

Line 12 Waste (kg) Commissioning 11/3/06

Process	Activity	Time			Total	Waste %	Comment
		10-1 am	1-3 pm	3-6 pm			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	0.00	0.00	2.00	2.00	0.17	
	Press 1	1.00	1.00	0.00	2.00	0.17	
	Press 2	1.00	1.00	0.00	2.00	0.17	
	Press 3	0.00	1.00	0.00	1.00	0.08	
Oven	After oven	146.00	1.00	12.00	159.00	13.22	
Cooling	Slide	0.00	0.00	0.00	0.00	0.00	
	By-Pass	109.00	105.00	90.00	304.00	25.27	Cavana 1 Problem 16 min 20 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine2	0.00	2.00	0.00	2.00	0.17	
	Guide Conveyer1	5.00	2.00	5.00	12.00	1.00	
	Guide Conveyer2	6.00	3.00	5.00	14.00	1.16	
Packing1	Cavana 1	30.00	5.00	20.00	55.00	4.57	
Packing2	Cavana 2	200.00	180.00	10.00	390.00	32.42	
Packaging1	end seal 1	30.00	20.00	5.00	55.00	4.57	
Packaging2	end seal 2	100.00	100.00	5.00	205.00	17.04	
Scrap		0.00	4.00	0.00	4.00		

Total waste	628.00	425.00	154.00	1203.00		
Accept Products	0.0	680.0	1911.0	2591.0		
Total	628.00	1105.00	2065.00	3794.00		
Line Efficiency %	0.0	61.5	92.5	68.3		
Waste %	100.0	38.5	7.5	31.7		
Total Process Waste = 96 kg ,9.33% of Total waste						
Total Packing Waste =914kg ,90.67 % of Total waste						
Dough waste = 1.09% of Total waste						
Biscuit waste = 60.81% of Total Waste						
Biscuit with wrapper waste = 38.1 % of Total Waste						

Line 12 Waste (kg) Commissioning 12/3/06

Process	Activity	Time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	Magnetic detector	0.00	0.00	1.00	0.00	1.00	0.13	
Laminating	Laminator	2.00	0.00	0.00	0.00	2.00	0.27	
	Press 1	0.00	1.00	0.00	0.00	1.00	0.13	
	Press 2	1.00	0.00	0.00	0.00	1.00	0.13	
	Press 3	1.00	0.00	1.00	0.00	2.00	0.27	
Oven	After oven	110	0.00	45.00	55.00	210.00	28.11	Start up Broken biscuit 25 min 30 sec
Cooling	Slide	8	0.00	0.00	0.00	8.00	1.07	
	By-Pass	80.00	45.00	20.00	10.00	155.00	20.75	
	Penny st. Guids1	2.00	0.00	0.00	0.00	2.00	0.27	
	Penny st. Guids2	2.00	6.00	0.00	0.00	8.00	1.07	
Aligning	Vibrator 1	1.00	0.00	0.00	0.00	1.00	0.13	
	Vibrator 2	1.00	0.00	0.00	0.00	1.00	0.13	
	Guide Bars Chine1	5.00	2.00	0.00	0.00	7.00	0.94	
	Guide Bars Chine2	6.00	0.00	0.00	0.00	6.00	0.80	
	Guide Conveyer1	10	0.00	0.00	0.00	10.00	1.34	

	Guide Conveyer2	10	0.00	0.00	0.00	10.00	1.34	
Packing1	Cavana 1	40.00	5.00	10.00	10.00	65.00	8.70	Cutting Wrapper 18 min 30 sec
Packing2	Cavana 2	45.00	60.00	25.00	10.00	140.00	18.74	
Packaging1	end seal 1	5.00	8.00	5.00	5.00	23.00	3.08	
Packaging2	end seal 2	25.00	40.00	20.00	9.00	94.00	12.58	
Scrap		4.00	7.00	6.00	7.00	24.00		
Total waste		358.00	174.00	133.00	106.00	747.00		
Accept Products		1496.0	2618.0	2244.0	2618.0	8976.0		
Total		1854.00	2792.00	2377.00	2724.00	9723.00		
Line Efficiency %		80.7	93.8	94.4	96.1	92.3		
Waste %		19.3	6.2	5.6	3.9	7.7		
Total Process Waste = 217 kg ,29.05% of Total waste								
Total Packing Waste =554 kg ,74.2 % of Total waste								
Dough waste = 0.94% of Total waste								
Biscuit waste = 55.96 % of Total Waste								
Biscuit with wrapper waste = 43.11 % of Total Waste								

Line 12 Waste (kg) Commissioning 13/3/06

Process	Activity	Time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	Magnetic detector	1.00	0.00	0.00	0.00	1.00	0.25	
Laminating	Laminator	0.00	1.00	0.00	1.00	2.00	0.50	
	Press 1	1.00	0.00	1.00	1.00	3.00	0.74	
	Press 2	0.00	1.00	0.00	0.00	1.00	0.25	
	Press 3	1.00	0.00	0.00	0.00	1.00	0.25	
Oven	After oven	25	12.00	1.00	2.00	40.00	9.93	Start up Broken biscuit 8 min 30 sec
Cooling	Slide	1	0.00	0.00	0.00	1.00	0.25	
	By-Pass	10.00	5.00	10.00	10.00	35.00	8.68	
	Penny st. Guids1	1.00	0.00	0.00	0.00	1.00	0.25	

	Penny st. Guids2	1.00	0.00	0.00	0.00	1.00	0.25	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	5.00	2.00	0.00	0.00	7.00	1.74	
	Guide Bars Chine2	6.00	3.00	0.00	2.00	11.00	2.73	
	Guide Conveyer1	0	2.00	5.00	0.00	7.00	1.74	
	Guide Conveyer2	1	0.00	5.00	2.00	8.00	1.99	
Packaing1	Cavana 1	25.00	10.00	10.00	20.00	65.00	16.13	Cutting Wrapper 12 min 45 sec
Packing2	Cavana 2	30.00	35.00	15.00	10.00	90.00	22.33	Cutting Wrapper 11 min 20 sec
Packaging1	end seal 1	10.00	8.00	11.00	10.00	39.00	9.68	
Packaging2	end seal 2	20.00	25.00	15.00	30.00	90.00	22.33	
Scrap		5.50	7.00	6.00	7.00	25.50		
Total waste		143.50	111.00	79.00	95.00	403.00		
Accept Products		1980.0	2618.0	2244.0	2618.0	9460.0		
Total		2123.50	2729.00	2323.00	2713.00	9863.00		
Line Efficiency %		93.2	95.9	96.6	96.5	95.9		
Waste %		6.8	4.1	3.4	3.5	4.1		
Total Process Waste = 48 kg ,11.9% of Total waste								
Total Packing Waste =380 kg ,94.3 % of Total waste								
Dough waste = 1.99% of Total waste								
Biscuit waste = 27.54% of Total Waste								
Biscuit with wrapper waste = 70.47% of Total Waste								

Line 12 Waste (kg) Commissioning 14/3/06								
Process	Activity	time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	0.00	0.00	1.00	0.00	1.00	0.21	
	Press 1	0.00	1.00	0.00	0.00	1.00	0.21	
	Press 2	0.00	0.00	1.00	0.00	1.00	0.21	
	Press 3	0.00	1.00	0.00	0.00	1.00	0.21	
Oven	After oven	29	14.00	80.00	2.00	125.00	26.48	Over Baking Biscuits 23 min 30 sec
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	
	By-Pass	0.00	20.00	10.00	30.00	60.00	12.71	
	Penny st. Guids1	0.00	0.00	1.00	0.00	1.00	0.21	
	Penny st. Guids2	1.00	0.00	1.00	2.00	4.00	0.85	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	1.00	0.00	0.00	0.00	1.00	0.21	
	Guide Bars Chine2	1.00	0.00	0.00	0.00	1.00	0.21	
	Guide Conveyer1	0	5.00	5.00	5.00	15.00	3.18	
	Guide Conveyer2	0	5.00	5.00	5.00	15.00	3.18	
Packing1	Cavana 1	20.00	20.00	10.00	15.00	65.00	13.77	Cutting Wrapper 24 min 20 sec
Packing2	Cavana 2	21.00	30.00	10.00	20.00	81.00	17.16	Cutting Wrapper 23 min 12 sec
Packaging1	end seal 1	10.00	10.00	10.00	0.00	30.00	6.36	
Packaging2	end seal 2	15.00	20.00	20.00	15.00	70.00	14.83	Adjustment Temperature Problem 12 min 14 sec
Scrap		4.50	7.00	7.00	7.50	26.00		
Total waste		102.50	133.00	161.00	101.50	472.00		
Accept Products		1683.0	2626.8	2618.0	4543.0	11470.8		
Total		1785.50	2759.80	2779.00	4644.50	11942.80		
Line Efficiency %		94.3	95.2	94.2	97.8	96.0		
Waste %		5.7	4.8	5.8	2.2	4.0		

Total Process Waste = 129 kg ,27.3 % of Total waste	
Total Packing Waste =369 kg ,78.2 % of Total waste	
Dough waste = 0.85 % of Total waste	
Biscuit waste = 47.03% of Total Waste	
Biscuit with wrapper waste = 52.12% of Total Waste	

Line 12 Waste (kg) Commissioning 15/3/06

Process	Activity	Time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	0.00	0.00	0.00	2.00	2.00	0.26	
	Press 1	0.00	2.00	1.00	1.00	4.00	0.51	
	Press 2	0.00	0.00	1.00	2.00	3.00	0.38	
	Press 3	0.00	1.00	1.00	1.00	3.00	0.38	
Oven	After oven	78	22.00	45.00	38.00	183.00	23.34	Start-up Broken Biscuits 23 min 10 sec
Cooling	Slide	0	0.00	1.00	0.00	1.00	0.13	
	By-Pass	160.00	40.00	10.00	5.00	215.00	27.42	
	Penny st. Guids1	1.00	0.00	0.00	0.00	1.00	0.13	
	Penny st. Guids2	2.00	0.00	0.00	0.00	2.00	0.26	
Aligning	Vibrator 1	0.00	0.00	2.00	0.00	2.00	0.26	
	Vibrator 2	1.00	0.00	0.00	0.00	1.00	0.13	
	Guide Bars Chine1	2.00	0.00	0.00	0.00	2.00	0.26	
	Guide Bars Chine2	0.00	30.00	3.00	0.00	33.00	4.21	
	Guide Conveyer1	0	30.00	11.00	10.00	51.00	6.51	
	Guide Conveyer2	3	0.00	12.00	0.00	15.00	1.91	
Packing1	Cavana 1	25.00	25.00	20.00	5.00	75.00	9.57	
Packing2	Cavana 2	30.00	35.00	21.00	5.00	91.00	11.61	
Packaging1	end seal 1	20.00	10.00	10.00	5.00	45.00	5.74	
Packaging2	end seal 2	20.00	20.00	10.00	5.00	55.00	7.02	

Scrap	3.00	7.00	7.00	7.50	24.50		
Total waste	345.00	222.00	155.00	86.50	784.00		
Accept Products	1122.0	2618.0	2618.0	2618.0	8976.0		
Total	1467.00	2840.00	2773.00	2704.50	9760.00		
Line Efficiency %	76.5	92.2	94.4	96.8	92.0		
Waste %	23.5	7.8	5.6	3.2	8.0		
Total Process Waste = 129 kg ,27.3 % of Total waste							
Total Packing Waste =369 kg ,78.2 % of Total waste							
Dough waste = 0.85 % of Total waste							
Biscuit waste = 47.03% of Total Waste							
Biscuit with wrapper waste = 52.12% of Total Waste							

Line 12 Waste (kg) Commissioning 30/3/06

Process	Activity	Time		Total	Waste %	Comment
		10-1 pm	3-6 pm			
Mixing	Magnetic detector	1.00	1.00	2.00	0.05	
Laminating	Laminator	1.00	1.00	2.00	0.05	
	Press 1	1.00	1.00	2.00	0.05	
	Press 2	1.00	1.00	2.00	0.05	
	Press 3	0.00	0.00	0.00	0.00	
Oven	After oven	225.00	280.00	505.00	12.30	Start up Broken biscuit 14 min 12 sec
Cooling	Slide	0.00	0.00	0.00	0.00	
	By-Pass	97.00	378.00	475.00	11.57	
	Penny st. Guids1	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	25.00	260.00	285.00	6.94	
	Vibrator 2	30.00	20.00	50.00	1.22	
	Guide Bars Chine1	50.00	30.00	80.00	1.95	
	Guide Bars Chine2	50.00	30.00	80.00	1.95	

	Guide Conveyer1	0.00	2.00	2.00	0.05	
	Guide Conveyer2	0.00	1.00	1.00	0.02	
Packing1	Cavana 1	48.00	495.00	543.00	13.22	Cutting Wrapper 16 min 20 sec
Packing2	Cavana 2	53.00	1218.00	1271.00	30.95	Cutting Wrapper 17 min 30 sec
Packaging1	end seal 1	100.00	522.00	622.00	15.14	
Packaging2	end seal 2	110.00	75.00	185.00	4.50	
Scrap		0.00	0.00	0.00		
Total waste		792.00	3315.00	4107.00		
Accept Products						
Total						
Line Efficiency %						
Waste %						
Total Process Waste = 48 kg ,11.9% of Total waste						
Total Packing Waste =380 kg ,94.3 % of Total waste						
Dough waste = 1.99% of Total waste						
Biscuit waste = 27.54% of Total Waste						
Biscuit with wrapper waste = 70.47% of Total Waste						

Line 12 Waste (kg)Commissioning 1/4/06							
Process	Activity	1Strat up 9-11 pm		4 2:30-4 pm	Total	Waste %	Comment
Mixing	Magnetic detector	0.00	Bagining to commissioning line	0.00	0.00	0.00	
Laminating	Laminator	1.00		2.00	3.00	0.18	
	Press 1	1.00		0.00	1.00	0.06	
	Press 2	0.00		2.00	2.00	0.12	
	Press 3	0.00		2.00	2.00	0.12	
Oven	After oven	150.00		70.00	220.00	13.10	Start up Broken biscuit, unusable Biscuits 24 min 2 sec
Cooling	Slide	10.00		0.00	10.00	0.60	
	By-Pass	85.00		22.00	107.00	6.37	
	Penny st. Guids1	0.00		0.00	0.00	0.00	
	Penny st. Guids2	0.00		0.00	0.00	0.00	
Aligning	Vibrator 1	2.00		0.00	2.00	0.12	
	Vibrator 2	2.00		0.00	2.00	0.12	
	Guide Bars Chine1	1.00		0.00	1.00	0.06	
	Guide Bars Chine2	1.00		0.00	1.00	0.06	
	Guide Conveyer1	32.00		6.00	38.00	2.26	
	Guide Conveyer2	32.00		21.00	53.00	3.15	
Packing1	Cavana 1	65.00		11.00	76.00	4.52	Cutting Wrapper 21 min 20 sec
Packing2	Cavana 2	77.00		25.00	102.00	6.07	Cutting Wrapper 20 min 30 sec
Packaging1	end seal 1	481.00		15.00	496.00	29.52	
Packaging2	end seal 2	481.00		83.00	564.00	33.57	
Scrap		23.00		35.00	58.00		
Total waste		1444.00		294.00	1680.00		
Accept Products		0.0		2241.0			
Total		1444.00		2535.00			
Line Efficiency %		0.0		88.4			
Waste %		100.0		11.6			

Total Process Waste = 48 kg ,11.9% of Total waste	
Total Packing(cavanna) Waste =218 kg ,74 % of Total waste	
Dough waste = 1.99% of Total waste	
Biscuit waste = 27.54% of Total Waste	
Biscuit with wrapper waste = 70.47% of Total Waste	

Line 12 Cavanna Waste (kg) Commissioning 2/4/06

stage	Activity	4 2:30-4 pm	Total	Waste %	Comment
conveyers	Slide	0.00	0.00	0.00	
	By-Pass	127.00	127.00	17.61	107 High moisture
	Penny st. Guids1	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	
	Vibrator 1	3.00	3.00	0.42	
	Vibrator 2	1.00	1.00	0.14	
	Guide Bars Chine1	2.00	2.00	0.28	
	Guide Bars Chine2	1.00	1.00	0.14	
	Guide Convoyer1	17.00	17.00	2.36	
	Guide Convoyer2	102.00	102.00	14.15	
packing	Cavana 1	60.00	60.00	8.32	
	Cavana 2	60.00	60.00	8.32	
	end seal 1	160.00	160.00	22.19	60 High moisture
	end seal 2	160.00	160.00	22.19	60 High moisture
Scrap		28.00	28.00		
Total waste		721.00	693.00		
Accept Products		290.4	290.4		
Total		1011.40	1011.40		
Line Efficiency %		28.7	28.7		
Waste %		71.3	71.3		

Line 12 Cavanna Waste (kg) Commissioning 4/4/06					
stage	Activity	4 11-5 pm	Total	Waste %	Comment
conveyers	Slide	8.00	8.00	1.23	
	By-Pass	108.00	108.00	16.67	
	Penny st. Guids1	2.00	2.00	0.31	
	Penny st. Guids2	8.00	8.00	1.23	
	Vibrator 1	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	
	Guide Bars Chine1	10.00	10.00	1.54	
	Guide Bars Chine2	1.00	1.00	0.15	
	Guide Convoyer1	19.00	19.00	2.93	
	Guide Convoyer2	48.00	48.00	7.41	
packing	Cavana 1	66.00	66.00	10.19	
	Cavana 2	97.00	97.00	14.97	
	end seal 1	146.00	146.00	22.53	Sealing problem
	end seal 2	105.00	105.00	16.20	
Scrap		30.00	30.00		
Total waste		648.00	634.00		
Accept Products		5079.8	10159.6		
Total		5727.80	5727.80		
Cavana Efficiency %		88.7	88.7		
Waste %		11.3	11.3		

Line 1B Cavanna Waste Commissioning 8/4/06							
stage	Area	Time			Total	Waste %	Comment
		10:20-12:10 pm	12:10-2:00 pM	2:00 - 6:10 pm			
conveyers	Slide	2.00	2.00	2.00	6.00	0.17	
	By-Pass	231.00	210.00	240.00	681.00	19.46	
	Penny st. Guids1	0.00	0.00	5.00	5.00	0.14	
	Penny st. Guids2	0.00	0.00	5.00	5.00	0.14	
	Vibrator 1	0.00	0.00	5.00	5.00	0.14	
	Vibrator 2	0.00	0.00	5.00	5.00	0.14	
	Guide Bars Chine1	1.00	5.00	3.00	9.00	0.26	
	Guide Bars Chine2	1.00	5.00	6.00	12.00	0.34	
	Guide Convoyer1	14.00	9.00	15.00	38.00	1.09	
	Guide Convoyer2	15.00	10.00	30.00	55.00	1.57	
packing	Cavana 1	32.00	50.00	130.00	212.00	6.06	
	Cavana 2	34.00	52.00	140.00	226.00	6.46	
	end seal 1	302.00	290.00	460.00	1052.00	30.07	
	end seal 2	418.00	201.00	355.00	974.00	27.84	
Scrap		16.00	10.00	188.00	214.00		
Total waste		1066.00	844.00	1589.00	3499.00		
Accept Products		0.0	0.0	0.0			
Total		1066.00	844.00	1589.00	1066.00		
Cavana Efficiency %		0.0	0.0		0.0		
Waste %		100.0			100.0		

Line 12 Cavanna Waste (kg) Commissioning 9/4/06						
Process	Activity	Time		Total	Waste %	Comment
		1:58-3:00 PM	3-6:20 PM			
Cooling	Slide	2.00	0.00	2.00	0.13	
	By-Pass	380.00	340.00	720.00	48.23	
	Penny st. Guids1	1.00	1.00	2.00	0.13	
	Penny st. Guids2	1.00	1.00	2.00	0.13	
Aligning	Vibrator 1	0.00	2.00	2.00	0.13	
	Vibrator 2	0.00	2.00	2.00	0.13	
	Guide Bars Chine1	2.00	0.00	2.00	0.13	
	Guide Bars Chine2	2.00	0.00	2.00	0.13	
	Guide Conveyer1	10.00	9.00	19.00	1.27	
	Guide Conveyer2	11.00	13.00	24.00	1.61	
Packing1	Cavana 1	48.00	60.00	108.00	7.23	
Packing2	Cavana 2	48.00	60.00	108.00	7.23	
Packaging1	end seal 1	196.00	25.00	221.00	14.80	
Packaging2	end seal 2	140.00	84.00	224.00	15.00	
Scrap		15.00	40.00	55.00		
Total waste		856.00	637.00	1493.00		
Accept Products		453.6	3074.4	3528.0		
Total		1309.60	3711.40	5021.00		
Cavana Efficiency %		34.6	82.8	70.3		
Waste %		65.4	17.2	29.7		

Line 12 Cavanna Waste (kg) Commissioning 10/4/06							
Process	Activity	Time			Total	Waste %	Comment
		8:45-10:00 AM	10:00-1:00 PM	1:00-5:15			
Cooling	Slide	2.00	0.00	0.00	2.00	0.10	
	By-Pass	380.00	50.00	484.00	914.00	47.58	
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	5.00	0.00	0.00	5.00	0.26	
Aligning	Vibrator 1	3.00	4.00	5.00	12.00	0.62	
	Vibrator 2	2.00	3.00	6.00	11.00	0.57	
	Guide Bars Chine1	8.00	5.00	5.00	18.00	0.94	
	Guide Bars Chine2	10.00	4.00	5.00	19.00	0.99	
	Guide Conveyer1	1.00	0.00	0.00	1.00	0.05	
	Guide Conveyer2	2.00	0.00	0.00	2.00	0.10	
Packing1	Cavana 1	36.00	66.00	76.00	178.00	9.27	
Packing2	Cavana 2	40.00	59.00	105.00	204.00	10.62	
Packaiging1	end seal 1	15.00	99.00	80.00	194.00	10.10	
Packaging2	end seal 2	55.00	70.00	220.00	345.00	17.96	
Scrap		2.00	6.00	8.00	16.00		
Total waste		561.00	366.00	994.00	1921.00		
Accept Products		1612.8	3225.6	3628.8	8467.2		
Total		2173.80	3591.60	4622.80	10388.20		
Cavana Efficiency %		74.2	89.8	78.5	81.5		
Waste %		25.8	10.2	21.5	18.5		

Line 12 Cavanna Waste (kg) Commissioning 11/4/06

Process	Activity	Time 8:45-10:00 AM	Time 10:00-1:00 PM	Good Products	Time 1:15-3:00	Good Products	Total	Waste %	Comment
Cooling	Slide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	102.00	203.00	0.00	30.00	0.00	335.00	15.83	
	Penny st. Guids1	0.00	1.00	0.00	1.00	0.00	2.00	0.09	
	Penny st. Guids2	0.00	0.00	0.00	2.00	0.00	2.00	0.09	
Aligning	Vibrator 1	0.00	0.00	0.00	3.00	0.00	3.00	0.14	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine2	0.00	0.00	0.00	2.00	0.00	2.00	0.09	
	Guide Conveyer1	0.00	5.00	0.00	3.00	0.00	8.00	0.38	
	Guide Conveyer2	0.00	5.00	0.00	4.00	0.00	9.00	0.43	
Packing1	Cavana 1	26.00	77.00	0.00	20.00	0.00	123.00	5.81	
Packing2	Cavana 2	28.00	28.00	0.00	23.00	0.00	79.00	3.73	
Packaging1	end seal 1	226.00	664.00	1102.00	148.00	795.00	1038.00	49.05	
Packaging2	end seal 2	230.00	183.00	1637.00	75.00	935.00	488.00	23.06	
Scrap		10.00	5.00	0.00	12.00	0.00	27.00		
Total waste		622.00	1171.00		323.00		2116.00		
Accept Products				2739.0		1730.0	4469.0		
Total							6585.00		
Cavana Efficiency %									
Waste %							32.1		

Line 12 Waste (kg) Commissioning 22/4/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	0.00	2.00	1.00	0.00	0.00	0.00	0.00	4.00	0.13	
	Press 1	1.00	1.00	1.00	0.00	2.00	2.00	1.00	0.00	8.00	0.26	
	Press 2	0.00	1.00	0.00	0.00	2.00	0.00	0.00	0.00	3.00	0.10	
	Press 3	0.00	0.00	1.00	0.00	0.00	1.00	0.00	1.00	3.00	0.10	
Oven	After oven	120	40.00	30.00	515.00	20.00	0.00	15.00	0.00	740.00	24.08	Bad appearance 27 min 33 sec
Cooling	Slide	0	2.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.07	
	By-Pass	60.00	75.00	40.00	280.00	161.00	320.00	102.00	120.00	1158.00	37.68	Hrnotch Problem 13 min 20sec
	Penny st. Guids1	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.07	
	Penny st. Guids2	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.13	
Aligning	Vibrator 1	3.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.16	
	Vibrator 2	2.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.16	
	Guide Bars Chine1	15.00	5.00	3.00	10.00	2.00	0.00	0.00	0.00	35.00	1.14	
	Guide Bars Chine2	20.00	6.00	3.00	20.00	2.00	2.00	0.00	0.00	53.00	1.72	
	Guide Conveyer1	2	0.00	2.00	0.00	20.00	25.00	21.00	5.00	75.00	2.44	
	Guide Conveyer2	1	6.00	5.00	0.00	20.00	26.00	22.00	6.00	86.00	2.80	
Packing1	Cavana 1	36.00	20.00	18.00	40.00	35.00	85.00	21.00	10.00	265.00	8.62	Jaws Problem 15 min 30 sec
Packing2	Cavana 2	40.00	26.00	12.00	30.00	40.00	105.00	23.00	8.00	284.00	9.24	SBF Louder Adjustment A,foulding box B 17 min 25 sec
Packaging1	end seal 1	40.00	18.00	10.00	15.00	25.00	40.00	10.00	5.00	163.00	5.30	
Packaging2	end seal 2	45.00	20.00	12.00	40.00	28.00	20.00	10.00	3.00	178.00	5.79	SBF Louder Adjustment A 24 min 20 sec
Scrap		8.00	7.00	5.00	11.00	10.00	11.00	5.00	2.00	59.00		
Total waste		400.00	232.00	144.00	962.00	367.00	637.00	230.00	160.00	3073.00		
Accept Products		1824.0	2352.0	2352.0	1778.4	1632.0	3004.8	2448.0	3672.0	19063.2		

Total	2224.00	2584.00	2496.00	2740.40	1999.00	3641.80	2678.00	3832.00	22136.20		
Line Efficiency %	82.0	91.0	94.2	64.9	81.6	82.5	91.4	95.8	86.1		
Waste %	18.0	9.0	5.8	35.1	18.4	17.5	8.6	4.2	13.9		
Total Process Waste = 34.5 kg ,9.7% of Total waste											
Total Packing Waste =321.5 kg ,90.3 % of Total waste											
Dough waste = 3.65% of Total waste											
Biscuit waste = 26.97% of Total Waste											
Biscuit with wrapper waste = 69.38 % of Total Waste											

Line 12 Waste (kg) Commissioning 23/4/06

Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminatin g	Laminator	1.00	0.00	0.00	2.00	0.00	0.00	2.00	1.00	6.00	0.34	
	Press 1	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.17	
	Press 2	0.00	1.00	0.00	1.00	0.00	1.00	0.00	1.00	4.00	0.23	
	Press 3	0.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	3.00	0.17	
Oven	After oven	50	10.00	120.00	525.00	30.00	70.00	1.00	0.00	806.00	46.08	Bad appearance 27 min 33 sec
Cooling	Slide	0	0.00	1.00	0.00	0.00	0.00	0.00	0.00	1.00	0.06	
	By-Pass	30.00	20.00	40.00	180.00	25.00	126.00	10.00	0.00	431.00	24.64	Cutter Adjusment B 18 min 20 sec
	Penny st. Guids1	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.11	
	Penny st. Guids2	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.17	
Aligning	Vibrator 1	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.06	
	Vibrator 2	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.06	
	Guide Bars Chine1	8.00	3.00	2.00	3.00	0.00	0.00	0.00	0.00	16.00	0.91	
	Guide Bars Chine2	7.00	5.00	3.00	5.00	0.00	0.00	0.00	0.00	20.00	1.14	
	Guide Conveyer1	1	0.00	0.00	1.00	11.00	0.00	0.00	0.00	13.00	0.74	

	Guide Conveyer2	1	0.00	0.00	2.00	12.00	4.00	0.00	0.00	19.00	1.09	
Packing1	Cavana 1	16.00	15.00	15.00	17.00	25.00	23.00	10.00	6.00	127.00	7.26	Jaws Problem15 min 30 sec
Packing2	Cavana 2	18.00	17.00	15.00	19.00	28.00	25.00	12.00	7.00	141.00	8.06	SBF Louder Adjustment A,foulding box B 19 min 26 sec
Packaging1	end seal 1	10.00	5.00	6.00	8.00	21.00	10.00	5.00	3.00	68.00	3.89	
Packaging2	end seal 2	20.00	8.00	7.00	10.00	21.00	11.00	5.00	2.00	84.00	4.80	SBF Louder Adjustment A 17 min 45 sec
Scrap		5.00	4.00	3.00	5.00	5.00	3.00	4.00	3.00	32.00		
Total waste		176.00	89.00	212.00	778.00	179.00	275.00	49.00	23.00	1749.00		
Accept Products		3264	3120	3264	3240	2856	3264	3264	4728	27000.0		
Total		3440.00	3209.00	3476.00	4018.00	3035.00	3539.00	3313.00	4751.00	28749.00		
Line Efficiency %		94.9	97.2	93.9	80.6	94.1	92.2	98.5	99.5	93.9		
Waste %		5.1	2.8	6.1	19.4	5.9	7.8	1.5	0.5	6.1		
Total Process Waste = 34.5 kg ,9.7% of Total waste												
Total Packing Waste =321.5 kg ,90.3 % of Total waste												
Dough waste = 3.65% of Total waste												
Biscuit waste = 26.97% of Total Waste												
Biscuit with wrapper waste = 69.38 % of Total Waste												

Line 12 Waste (kg) Commissioning 24/4/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm	7-10 pm	10-1 pm	1-3 am	3-6 am			
Mixing	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Laminatin g	Laminator	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2.00	0.13	
	Press 1	1.00	0.00	1.00	0.00	0.00	1.00	2.00	0.00	5.00	0.33	
	Press 2	0.00	2.00	0.00	0.00	0.00	0.00	1.00	0.00	3.00	0.20	
	Press 3	0.00	1.00	1.00	0.00	0.00	0.00	2.00	0.00	4.00	0.26	
Oven	After oven	20	40.00	20.00	15.00	25.00	5.00	0.00	10.00	135.00	8.79	Bad appearance 22 min 20 sec
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	40.00	100.00	30.00	50.00	10.00	35.00	10.00	75.00	350.00	22.80	Cavanna Problem 23 min 30 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.20	0.01	
	Vibrator 2	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.20	0.01	
	Guide Bars Chine1	8.00	5.00	2.00	6.00	0.00	0.00	0.00	0.00	21.00	1.37	
	Guide Bars Chine2	10.00	15.00	2.00	8.00	0.00	0.00	0.00	0.00	35.00	2.28	
	Guide Conveyer1	0.1	0.20	0.00	0.10	11.00	0.00	0.00	16.00	27.40	1.78	
	Guide Conveyer2	0.1	0.10	0.00	0.05	10.00	0.00	5.00	23.00	38.25	2.49	
Packing1	Cavana 1	20.00	25.00	15.00	25.00	11.00	30.00	60.00	126.00	312.00	20.33	Broken biscuits 27 min 22 sec
Packing2	Cavana 2	20.00	25.00	18.00	25.00	5.00	45.00	65.00	143.00	346.00	22.54	Broken biscuits 25 min 45 sec
Packaging1	end seal 1	18.00	16.00	4.00	15.00	15.00	12.00	5.00	37.00	122.00	7.95	
Packaging2	end seal 2	18.00	20.00	8.00	18.00	18.00	11.00	3.00	38.00	134.00	8.73	
Scrap		5.00	3.00	5.00	16.00	3.00	2.00	3.00	10.00	47.00		
Total waste		160.20	252.50	106.00	178.35	110.00	141.00	156.00	478.00	1535.05		
Accept Products		3240	3600	3840	3360	3938	4080	2856	2856	27770.4		
Total		3400.20	3852.50	3946.00	3538.35	4048.40	4221.00	3012.00	3334.00	29305.45		
Line Efficiency %		95.3	93.4	97.3	95.0	97.3	96.7	94.8	85.7	94.8		
Waste %		4.7	6.6	2.7	5.0	2.7	3.3	5.2	14.3	5.2		

Total Process Waste = 34.5 kg ,9.7% of Total waste	
Total Packing Waste =321.5 kg ,90.3 % of Total waste	
Dough waste = 3.65% of Total waste	
Biscuit waste = 26.97% of Total Waste	
Biscuit with wrapper waste = 69.38 % of Total Waste	

Line 12 Waste (kg) Commissioning 25/4/06

Process	Activity	Time								Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-7 pm	7-10 pm	10-1 pm	1-3 am	3-7 am			
Mixing	Magnetic detector	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.10	
Laminating	Laminator	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Press 1	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.05	
	Press 2	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	2.00	0.10	
	Press 3	0.00	0.00	1.00	0.00	0.00	0.00	1.00	0.00	2.00	0.10	
Oven	After oven	385	10.00	7.00	88.00	20.00	0.00	0.00	3.00	513.00	24.93	Bad appearance 25 min 39 sec
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	50.00	100.00	50.00	200.00	143.00	20.00	25.00	40.00	628.00	30.52	Cavanna Problem 18 min 20 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.10	0.05	0.00	0.00	0.00	0.00	0.00	0.15	0.01	
	Vibrator 2	0.00	0.10	0.06	0.00	0.00	0.00	0.00	0.00	0.16	0.01	
	Guide Bars Chine1	3.00	7.00	3.00	2.00	0.00	0.00	0.00	0.00	15.00	0.73	
	Guide Bars Chine2	10.00	15.00	9.00	3.00	0.00	0.00	0.00	0.00	37.00	1.80	
	Guide Conveyer1	0	0.20	0.00	0.05	20.00	10.00	0.00	10.00	40.25	1.96	
	Guide Conveyer2	0	0.30	0.00	0.05	23.00	5.00	0.00	15.00	43.35	2.11	
Packing1	Cavana 1	20.00	15.00	25.00	40.00	52.00	25.00	10.00	10.00	197.00	9.57	Broken biscuits1 8 min 44 sec
Packing2	Cavana 2	20.00	17.00	30.00	80.00	54.00	26.00	8.00	30.00	265.00	12.88	Broken biscuits 17 min 35 sec
Packaging1	end seal 1	5.00	20.00	40.00	25.00	12.00	15.00	5.00	30.00	152.00	7.39	

Packaging2	end seal 2	10.00	28.00	3.00	75.00	13.00	18.00	3.00	10.00	160.00	7.77	
Scrap		5.00	4.00	3.00	4.00	5.00	3.00	2.00	5.00	31.00		
Total waste		510.00	217.70	171.11	518.10	342.00	123.00	54.00	153.00	2057.91		
Accept Products		854	851	854	851	2739	2739	2739	2739	14366.0		
Total		1363.60	1069.10	1024.71	1369.50	3081.00	2862.00	2793.00	2892.00	16423.91		
Line Efficiency %		62.6	79.6	83.3	62.2	88.9	95.7	98.1	94.7	87.5		
Waste %		37.4	20.4	16.7	37.8	11.1	4.3	1.9	5.3	12.5		
Total Process Waste = 34.5 kg ,9.7% of Total waste												
Total Packing Waste =321.5 kg ,90.3 % of Total waste												
Dough waste = 3.65% of Total waste												
Biscuit waste = 26.97% of Total Waste												
Biscuit with wrapper waste = 69.38 % of Total Waste												

Line 12 Waste (kg) Commissioning 17/5/06

Process	Activity	Time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	No. of Batches	6	7	5	8	26		
	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	1.00	1.00	0.00	1.00	3.00	0.11	
	Press 1	1.00	0.00	0.00	0.00	1.00	0.04	
	Press 2	0.00	0.00	0.00	1.00	1.00	0.04	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	795	10.00	15.00	5.00	825.00	31.50	high Moisture 28 min 20 sec
Cooling	Slide	0	0.00	0.00	0	0.00	0.00	
	By-Pass	120.00	233.00	120.00	283.00	756.00	28.87	Oven bad Appearance , sliding problem 18 min 25 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.10	0.00	8.00	8.10	0.31	
	Vibrator 2	0.00	0.20	0.00	25.00	25.20	0.96	

	Guide Bars Chine1	3.00	2.00	2.00	12.00	19.00	0.73	
	Guide Bars Chine2	5.00	10.00	7.00	10.00	32.00	1.22	
	Guide Conveyer1	0	0.10	0.20	0.10	0.40	0.02	
	Guide Conveyer2	0	0.05	0.00	0.05	0.10	0.00	
Packing1	Cavana 1	25.00	75.00	50.00	200.00	350.00	13.36	Bad Sealing ,Broken biscuits ,adjustiment of wrapper timing 22 min 20 sec
Packing2	Cavana 2	25.00	90.00	45.00	50.00	210.00	8.02	Bad Sealing 20 min 30 sec
Packaging1	end seal 1	18.00	70.00	15.00	45.00	148.00	5.65	Bad Sealing 18 min 27 sec
Packaging2	end seal 2	18.00	90.00	25.00	50.00	183.00	6.99	Bad Sealing 19 min 33 sec
Scrap		7.00	20.00	15.00	15.00	57.00		
Total waste		1016.00	600.45	294.20	703.15	2618.80		
Accept Products		0	3024	3326	3382	9732.2		
Total		1016.00	3624.45	3620.60	4084.99	12351.04		
Line Efficiency %		0.0	83.4	91.9	82.8	78.8		
Waste %		100.0	16.6	8.1	17.2	21.2		
Total Process Waste = 830kg ,22.4% of Total waste								
Total Packing(cavanna) Waste =1788.8 kg ,67.6 % of Total waste								
Total no. of accepted cartons = 1931 cts = 9732.2 kg								
Total no. of cartons must be produced = 2444 cts = 12317.8 kg								
Total Waste from satndard =2585.6								
Dough waste = 0.13% of Total waste								
Biscuit waste = 65.2% of Total Waste								
Biscuit with wrapper waste = 33.7% of Total Waste								

Line 12 Waste (kg) Commissioning 18/5/06								
Process	Activity	Time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	No. of Batches	8	8	5	5	26		
	Magnetic detector	0.00	0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator	0.00	1.00	0.00	1.00	2.00	0.22	
	Press 1	1.00	0.00	0.00	0.00	1.00	0.11	
	Press 2	0.00	0.00	1.00	0.00	1.00	0.11	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	235	25.00	5.00	30.00	295.00	31.75	High Moisture 28 min 35 sec
Cooling	Slide	0	0.00	0.00	0	0.00	0.00	
	By-Pass	88.00	44.00	0.00	114.00	246.00	26.47	Slide Problem , Gap 25 min 48 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.05	0.05	0.00	0.00	0.10	0.01	
	Vibrator 2	22.00	1.00	0.00	0.00	23.00	2.48	
	Guide Bars Chine1	1.00	3.00	2.00	5.00	11.00	1.18	
	Guide Bars Chine2	1.00	2.00	2.00	4.00	9.00	0.97	
	Guide Conveyer1	0.05	0.00	0.00	0.00	0.05	0.01	
	Guide Conveyer2	0	0.00	0.00	0.05	0.05	0.01	
Packing1	Cavana 1	20.00	39.00	17.00	17.00	93.00	10.01	
Packing2	Cavana 2	16.00	35.00	17.00	21.00	89.00	9.58	
Packaging1	end seal 1	9.00	12.00	5.00	2.00	28.00	3.01	
Packaging2	end seal 2	22.00	50.00	40.00	2.00	114.00	12.27	Long Sealing Problem 20 min 30 sec
Scrap		5.00	3.00	5.00	4.00	17.00		
Total waste		419.10	214.05	93.00	199.05	929.20		
Accept Products		1512	3629	2419	4007	11566.8		
Total		1931.10	3842.85	2512.20	4205.85	12496.00		
Line Efficiency %		78.3	94.4	96.3	95.3	92.6		
Waste %		21.7	5.6	3.7	4.7	7.4		

Total Process Waste	545.00	% of waste	58.7		
Total Packing(cavanna) Waste	384.20	% of waste	41.3	% of Cavannae waste from total	3.1
Total no. of accepted cartons	2295	Total Accepted in kg	11566.8		
Total no. of cartons must be produced	2444	Total muste be in kg	12317.8		
Total packe Waste from satndard	149	Total waste from standard	750.96		
Dough waste	4.00	Dough Waste %	0.4		
Biscuit waste	601.20	Biscuit waste %	64.7		
Biscuit with wrapper waste	324.00	Biscuit with Wrapper waste %	34.9		
Total run time in min	564	Time in hour	9.4		
Leg 1 in min	3	% of Down time in leg 1	0.5		
Leg2 in min	12	% of Down time in leg 2	2.1		

Line 12 Waste (kg) Commissioning 20/5/06

Process	Activity	Time				Total	Waste %	Comment
		7-10am	10-1 pm	1-3 pm	3-6 pm			
Mixing	No. of Batches		3	3	2	8		
	Magnetic detector		0.00	0.00	0.00	0.00	0.00	
Laminating	Laminator		0.00	0.00	0.00	0.00	0.00	
	Press 1		1.00	0.00	1.00	2.00	0.11	
	Press 2		0.00	0.00	2.00	2.00	0.11	
	Press 3		0.00	0.00	0.00	0.00	0.00	
Oven	After oven		180.00	0.00	260.00	440.00	24.03	Start up ,Unshaped 19 min 20 sec
Cooling	Slide		0.00	0.00	0	0.00	0.00	
	By-Pass		190.00	250.00	459.00	899.00	49.10	unshaped , Adjustment of m/c, Air pressure cav2 29 min 50 sec
	Penny st. Guids1		0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2		0.00	0.00	0.00	0.00	0.00	
Allignin g	Vibrator 1		0.00	0.00	0.00	0.00	0.00	
	Vibrator 2		0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1		0.00	0.00	0.00	0.00	0.00	

	Guide Bars Chine2		0.00	0.00	0.00	0.00	0.00		
	Guide Conveyer1		0.00	0.00	0.00	0.00	0.00		
	Guide Conveyer2		0.00	0.00	0.00	0.00	0.00		
Packing1	Cavana 1		50.00	51.00	50.00	151.00	8.25		
Packing2	Cavana 2		18.00	25.00	20.00	63.00	3.44	Air Pressure Problem 18 min 30 sec	
Packaging1	end seal 1		22.00	22.00	15.00	59.00	3.22	Good Packets kg	1056.00
Packaging2	end seal 2		14.00	100.00	85.00	199.00	10.87	Good Packets kg	443.00
Scrap			5.00	3.00	8.00	16.00			
Total waste			479.00	451.00	897.00	1831.00			
Accept Products			490	495	504	1489.0			
Total			969.00	946.00	1401.00	3320.00			
Line Efficiency %			50.6	52.3	36.0	44.8			
Waste %			49.4	47.7	64.0	55.2			
Total Process Waste		444.00	% of waste		24.2				
Total Packing(cavanna) Waste		738.00	% of waste		40.3	% of Cavannae waste from total		22.2	
Total no. of accepted cartons		295	Total Accepted in kg			1486.8			
Total no. of cartons must be produced		752	Total muste be in kg			3790.08			
Total packe Waste from satndard		457	Total waste from standard			2303.28			
Dough waste		4.00	Dough Waste %			0.2			
Biscuit waste		1355.00	Biscuit waste %			74.0			
Biscuit with wrapper waste		472.00	Biscuit with Wrapper waste %			25.8			
Total run time in min		315	Time in hour			5.3			
Leg 1 in min		181	% of Down time in leg 1			57.5			
Leg2 in min		250	% of Down time in leg 2			79.4			

Line 12 Waste(kg) Commissioning 21/5/06										
Process	Activity	Time						Total	Waste %	Comment
		1-3am	3-7 pm	7-10 pm	10-1 am	1-3 am	3-7 am			
Mixing	No. of Batches	5	6	5	6	5	5	32		
	Magnetic detector	4.00	1.00	0.00	0.00	0.00	0.00	5.00	0.34	
Laminatin g	Laminator	1.00	0.00	0.00	0.00	0.00	2.00	3.00	0.21	
	Press 1	1.00	1.00	0.00	0.00	0.00	1.00	3.00	0.21	
	Press 2	0.00	2.00	0.00	0.00	0.00	0.00	2.00	0.14	
	Press 3	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.07	
Oven	After oven	200	10.00	1.00	1.00	1.00	1.00	214.00	14.72	High Mouisure 25 min 20 sec
Cooling	Slide	0	0.00	0.00	0	0.00	0.00	0.00	0.00	
	By-Pass	92.00	35.00	60.00	80.00	20.00	10.00	297.00	20.43	Cavana Adjustmints A,Gap A 22 min 33 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	Guide Bars Chine1	18.00	14.00	0.00	0.00	0.00	0.00	32.00	2.20	
	Guide Bars Chine2	10.00	14.00	0.00	0.00	0.00	0.00	24.00	1.65	
	Guide Conveyer1	6	3.00	15.00	5.00	20.00	0.00	49.00	3.37	
	Guide Conveyer2	2	3.00	20.00	6.00	5.00	5.00	41.00	2.82	
Packing1	Cavana 1	100.00	3.00	63.00	30.00	20.00	10.00	226.00	15.54	Broken Biscuits 22 30 sec
Packing2	Cavana 2	85.00	34.00	61.00	33.00	10.00	11.00	234.00	16.09	Broken Biscuits 21 min 10 sec
Packaging1	end seal 1	92.00	34.00	11.00	9.00	5.00	2.00	153.00	10.52	Broken Biscuits 27 min 2 sec
Packaging2	end seal 2	70.00	35.00	9.00	12.00	5.00	2.00	133.00	9.15	Broken Biscuits 26 min 2 sec
Scrap		12.00	10.00	5.00	3.00	2.00	5.00	37.00		
Total waste		687.00	195.00	245.00	179.00	88.00	46.00	1454.00		
Accept Products		1080	1706	2106	2117	2106	2117	11232.0		
Total		1767.00	1901.40	2351.00	2295.80	2194.00	2162.80	12686.00		
Line Efficiency %		61.1	89.7	89.6	92.2	96.0	97.9	88.5		

Waste %	38.9	10.3	10.4	7.8	4.0	2.1	11.5						
Total Process Waste	525.00	% of waste		36.1									
Total Packing(cavanna) Waste	929.00	% of waste		63.9			% of Cavannae waste from total				7.3		
Total no. of accepted cartons	5200	Total Accepted in kg					11232						
Total no. of cartons must be produced	7440	Total muste be in kg					16070.4						
Total packe Waste from satndard	2240	Total waste from standard					4838.4						
Dough waste	14.00	Dough Waste %					1.0						
Biscuit waste	694.00	Biscuit waste %					47.7						
Biscuit with wrapper waste	746.00	Biscuit with Wrapper waste %					51.3						
Total run time in min A		Time in hour						Total run time in min B			hour		
Leg 1 in min A		% of Down time in leg 1						Leg 1 in min B			%		
Leg2 in min A		% of Down time in leg 2						Leg 2 in min B			%		

Line 12 Waste(kg) Commissioning 22/5/06

Process	Activity	Time				Total	Waste %	Comment
		1-3 pm	3-7 pm	7-10 pm	10-1 am			
Mixing	No. of Batches	5	5	6	5	21		
	Magnetic detector	0.00	1.00	0.00	0.00	1.00	0.11	
Laminating	Laminator	0.00	2.00	0.00	0.00	2.00	0.22	
	Press 1	0.00	0.00	1.00	0.00	1.00	0.11	
	Press 2	0.00	1.00	0.00	0.00	1.00	0.11	
	Press 3	0.00	0.00	1.00	0.00	1.00	0.11	
Oven	After oven	60	95.00	60.00	85.00	300.00	32.53	
Cooling	Slide	0	0.00	0.00	0	0.00	0.00	
	By-Pass	45.00	22.00	20.00	153.00	240.00	26.02	Cavana Adjustments 16 min 30 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	0.00	

Aligning	Vibrator 1	1.00	0.00	0.00	1.00	2.00	0.22	
	Vibrator 2	1.00	0.00	0.00	1.00	2.00	0.22	
	Guide Bars Chine1	2.00	5.00	5.00	9.00	21.00	2.28	
	Guide Bars Chine2	1.00	4.00	6.00	8.00	19.00	2.06	
	Guide Conveyer1	0.1	0.00	0.05	0.10	0.25	0.03	
	Guide Conveyer2	0	0.05	0.05	0.00	0.10	0.01	
Packing1	Cavana 1	38.00	31.00	16.00	26.00	111.00	12.03	Broken Biscuits 22 min 20 sec
Packing2	Cavana 2	30.00	17.00	16.00	29.00	92.00	9.97	
Packaging1	end seal 1	19.00	12.00	8.00	10.00	49.00	5.31	
Packaging2	end seal 2	8.00	11.00	7.00	27.00	53.00	5.75	
Scrap		5.00	7.00	8.00	7.00	27.00		
Total waste		210.10	204.05	146.10	356.10	922.35		
Accept Products		2583	2592	2484	2268	9927.4		
Total		2793.46	2796.05	2630.10	2624.10	10849.71		
Line Efficiency %		92.5	92.7	94.4	86.4	91.5		
Waste %		7.5	7.3	5.6	13.6	8.5		
Total Process Waste		546.00	% of waste		59.2			
Total Packing(cavanna) Waste		376.35	% of waste		40.8	% of Cavannae waste from total		3.5
Total no. of accepted cartons		4596	Total Accepted in kg			9927.36		
Total no. of cartons must be produced		4882.5	Total muste be in kg			10546.2		
Total pack Waste from standard		286.5	Total waste from standard			618.84		
Dough waste		6.00	Dough Waste %			0.7		
Biscuit waste		611.35	Biscuit waste %			66.3		
Biscuit with wrapper waste		305.00	Biscuit with Wrapper waste %			33.1		
Total run time in min A		695	Time in hour			11.5		
Leg 1 in min A		30	% of Down time in leg 1			4.3		
Leg2 in min A		15	% of Down time in leg 2			2.2		

Line 12 Waste (kg) Commissioning 23/5/06											
Process	Activity	Time							Total	Waste %	Comment
		10-1am	1-3 pm	4-7 pm	7-10 pm	10-1 pm	1-3 am	4-7 am			
Mixing	No. of Batches	3	3	2					8		
	Magnetic detector	0.00	2.00	0.00					2.00	0.31	
Laminatin g	Laminator	0.00	1.00	0.00					1.00	0.15	
	Press 1	1.00	0.00	0.00					1.00	0.15	
	Press 2	0.00	2.00	0.00					2.00	0.31	
	Press 3	0.00	0.00	0.00					0.00	0.00	
Oven	After oven	10.5	90.00	0.00					100.50	15.54	High Mouisure A 23 min 20 sec
Cooling	Slide	0	0.00	0.00					0.00	0.00	
	By-Pass	162.00	23.00	22.00					207.00	32.00	High Mouisure A 20 min 20 sec
	Penny st. Guids1	0.00	0.00	0.00					0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00					0.00	0.00	
Aligning	Vibrator 1	0.00	1.00	0.00					1.00	0.15	
	Vibrator 2	0.00	1.00	0.00					1.00	0.15	
	Guide Bars Chine1	0.00	2.00	4.00					6.00	0.93	
	Guide Bars Chine2	0.00	3.00	5.00					8.00	1.24	
	Guide Conveyer1	0	0.10	0.10					0.20	0.03	
	Guide Conveyer2	0	0.05	0.10					0.15	0.02	
Packing1	Cavana 1	0.00	17.00	25.00					42.00	6.49	Broken Biscuits 22 min 10 sec
Packing2	Cavana 2	0.00	50.00	25.00					75.00	11.59	Broken Biscuits 23 min 20 sec
Packaging1	end seal 1	36.00	12.00	24.00					72.00	11.13	
Packaging2	end seal 2	37.00	46.00	30.00					113.00	17.47	
Scrap		0.00	5.00	10.00					15.00		
Total waste		245.50	250.15	145.20	0.00	0.00	0.00	0.00	646.85		
Accept Products		864	1728	1056					3648.2		
Total		1109.50	1978.15	1201.44	0.00	0.00	0.00	0.00	4295.09		
Line Efficiency %		77.9	87.4	87.9	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	84.9		

Waste %	22.1	12.6	12.1	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	15.1						
Total Process Waste	313.50	% of waste		48.5										
Total Packing(cavanna) Waste	333.35	% of waste		51.5				% of Cavannae waste from total				7.8		
Total no. of accepted cartons	1689	Total Accepted in kg						4053.6						
Total no. of cartons must be produced	1860	Total muste be in kg						4464						
Total packe Waste from satndard	171	Total waste from standard						410.4						
Dough waste	6.00	Dough Waste %						0.9						
Biscuit waste	338.85	Biscuit waste %						52.4						
Biscuit with wrapper waste	302.00	Biscuit with Wrapper waste %						46.7						
Total run time in min A	450	Time in hour						7.5	Total run time in min B		660	hour	11	
Leg 1 in min A	5	% of Down time in leg 1						1.1	Leg 1 in min B		19	%	2.9	
Leg2 in min A	10	% of Down time in leg 2						2.2	Leg 2 in min B		17	%	2.6	

Line 12 Waste (kg) Commissioning 24/5/06												
Process	Activity	Time								Total	Waste %	Comment
		7-10 am	10-1 pm	1-3 pm	4-7 pm	7-10 pm	10-1 am	1-3 am	4-7 am			
Mixing	No. of Batches	7	8	8	7	8	8	8	8	62		
	Magnetic detector	2.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	6.00	0.43	
Laminating	Laminator	0.00	1.00	0.00	0.00	1.00	1.00	1.00	0.00	4.00	0.29	
	Press 1	0.00	0.00	2.00	2.00	0.00	0.00	0.00	1.00	5.00	0.36	
	Press 2	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	2.00	0.14	
	Press 3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Oven	After oven	0	150.00	0.00	0.00	2.00	1.00	3.00	23.00	179.00	12.87	Bad Appearance A 25 min 30 sec,Broken biscuits B 12 min 20 sec
Cooling	Slide	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
	By-Pass	146.00	60.00	24.00	64.00	15.00	35.00	15.00	5.00	364.00	26.16	Machine Adjustmint A,Gap A 25 min 30 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.07	
	Penny st. Guids2	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.07	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	2.00	0.14	
	Vibrator 2	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.07	
	Guide Bars Chine1	3.00	1.00	1.00	3.00	0.00	1.00	0.00	0.00	9.00	0.65	
	Guide Bars Chine2	2.00	1.00	1.00	2.00	0.00	2.00	0.00	0.00	8.00	0.58	
	Guide Conveyer1	0.05	0.05	0.00	0.05	2.00	10.00	5.00	5.00	22.15	1.59	
	Guide Conveyer2	0	0.05	0.00	0.05	3.00	12.00	2.00	5.00	22.10	1.59	
Packing1	Cavana 1	18.00	20.00	18.00	39.00	26.00	21.00	21.00	22.00	185.00	13.30	Broken Biscuits (Twin Packs) 20 min 40 sec
Packing2	Cavana 2	33.00	16.00	36.00	40.00	20.00	20.00	22.00	23.00	210.00	15.09	Broken Biscuits(Twin Packs)18 min 20 sec
Packaging1	end seal 1	23.00	32.00	24.00	35.00	5.00	5.00	10.00	5.00	139.00	9.99	Bad side sealingA 15 min 20 sec, Broken biscuitsA 10 min 30 sec

Packaging2 end seal 2	28.00	54.00	39.00	59.00	6.00	4.00	2.00	2.00	194.00	13.94	Bad side sealingA 17 min 55 sec, Broken biscuitsA 18 min 20 sec	
Scrap	8.00	5.00	5.00	6.00	2.00	5.00	3.00	3.00	37.00			
Total waste	261.05	339.10	148.00	248.10	81.00	121.00	83.00	93.00	1391.25			
Accept Products	2880	3600	3360	3624	4080	4080	2856	5304	29784.0			
Total	3141.05	3939.10	3508.00	3872.10	4161.00	4201.00	2939.00	5397.00	31175.25			
Line Efficiency %	91.7	91.4	95.8	93.6	98.1	97.1	97.2	98.3	95.5			
Waste %	8.3	8.6	4.2	6.4	1.9	2.9	2.8	1.7	4.5			
Total Process Waste	560.00	% of waste		40.3								
Total Packing(cavanna) Waste	831.25	% of waste		59.7					% of Cavannae waste from total 2.7			
Total no. of accepted cartons	9010	Total Accepted in kg						21624				
Total no. of cartons must be produced	12008	Total muste be in kg						28818.096				
Total packe Waste from satndard	2997.5	Total waste from standard						7194.096				
Dough waste	17.00	Dough Waste %						1.2				
Biscuit waste	646.25	Biscuit waste %						46.5				
Biscuit with wrapper waste	728.00	Biscuit with Wrapper waste %						52.3				
Total run time in min A	720	Time in hour						12.0	Total run time in min B	720	hour	12
Leg 1 in min A	23	% of Down time in leg 1						3.2	Leg 1 in min B	10	%	1.4
Leg2 in min A	26	% of Down time in leg 2						3.6	Leg 2 in min B	12	%	1.7

Line 12 Waste (kg) Commissioning 25/5/06

Process	Activity	Time					Total	Waste %	Comment
		7-10 am	10-1 pm	1-3 pm	4-7 pm	4-7 am			
Mixing	No. of Batches	8.0	7.5	7.0	8.0		30.5		
	Magnetic detector	0.00	0.00	0.00	1.00		1.00	0.19	
Laminating	Laminator	1.00	0.00	0.00	2.00		3.00	0.56	
	Press 1	0.00	0.00	0.00	1.00		1.00	0.19	
	Press 2	0.00	0.00	1.00	0.00		1.00	0.19	
	Press 3	1.00	0.00	0.00	1.00		2.00	0.37	
Oven	After oven	40	0.00	0.00	0.00		40.00	7.46	Bad appearance 23 min 40 sec
Cooling	Slide	0	0.00	0.00	0.00		0.00	0.00	
	By-Pass	45.00	20.00	39.00	25.00		129.00	24.06	Gap from oven 15 min 20 sec
	Penny st. Guids1	0.00	0.00	0.00	0.00		0.00	0.00	
	Penny st. Guids2	0.00	0.00	0.00	0.00		0.00	0.00	
Aligning	Vibrator 1	0.00	0.00	0.00	0.00		0.00	0.00	
	Vibrator 2	0.00	0.00	0.00	0.00		0.00	0.00	
	Guide Bars Chine1	2.00	4.00	0.00	3.00		9.00	1.68	
	Guide Bars Chine2	1.00	4.00	0.00	5.00		10.00	1.87	
	Guide Conveyer1	0.05	0.00	0.00	0.00		0.05	0.01	
	Guide Conveyer2	0	0.05	0.00	0.00		0.05	0.01	
Packing1	Cavana 1	16.00	20.00	12.00	16.00		64.00	11.94	
Packing2	Cavana 2	15.00	16.00	20.00	18.00		69.00	12.87	
Packaging1	end seal 1	15.00	6.00	8.00	15.00		44.00	8.21	
Packaging2	end seal 2	59.00	39.00	18.00	23.00		139.00	25.93	broken biscuits 20 min 30 sec
Scrap		6.00	5.00	8.00	5.00		24.00		
Total waste		199.05	114.05	105.00	110.00	0.00	536.10		
Accept Products		3079	3600	3360	4080		14119.2		
Total		3278.25	3714.05	3465.00	4190.00	0.00	14655.30		
Line Efficiency %		93.9	96.9	97.0	97.4	#DIV/0!	96.3		
Waste %		6.1	3.1	3.0	2.6	#DIV/0!	3.7		

Total Process Waste	177.00	% of waste	33.0				
Total Packing(cavanna) Waste	359.10	% of waste	67.0	% of Cavannae waste from total		2.5	
Total no. of accepted cartons	5883	Total Accepted in kg	14119.2				
Total no. of cartons must be produced	5906.9	Total muste be in kg	14176.644				
Total packe Waste from satndard	23.935	Total waste from standard	57.444				
Dough waste	8.00	Dough Waste %	1.5				
Biscuit waste	212.10	Biscuit waste %	39.6				
Biscuit with wrapper waste	316.00	Biscuit with Wrapper waste %	58.9				
Total run time in min A	705	Time in hour	11.8	Total run time in min B		hour	
Leg 1 in min A	7	% of Down time in leg 1	1.0	Leg 1 in min B		%	
Leg2 in min A	9	% of Down time in leg 2	1.3	Leg 2 in min B		%	

Appendix B Line 12 Standard Operating Procedure (SOP)

1. PURPOSE & SCOPE:

The purpose of this Procedure is to describe the process of hard biscuit manufacturing.

2. SCOPE:

This procedure is applied to Line 12 only.

2. REFERENCES :

- **ISO 9001 (2000) - Clause 7.5.2**
- **Quality Manual - Clause 7.5.2**

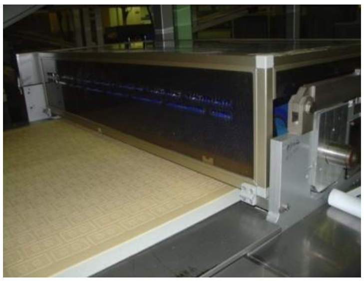
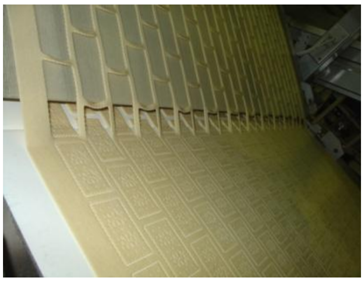
3. DEFINATONS:

- **None**

4. RESPONSIBILTY:
- **Production Operators**
- **Production Leadsmen**
- **Production In charge**

Responsibility	Process description	ref	Process Picture
Production supervisor Silo operator Mixing Operator	**5.1 Ingredient Mixing** 5.1.1 Production Supervisor will communicate the product change over to silo & mixer operator and they will select recipe from the system. 5.1.2 And silo system will feed the ingredients (Flour, Water and sugar) automatically to the mixing section. The silo operation is described in Silo Work Instruction 5.1.3 All other ingredients (invert syrup, milk powder, Chemicals etc) are weighed and added to the mixer manually as per the standard product recipe. 5.1.4 Mixing is carried out in 3 stages as per the mixing work	WI/PD/02//01 WI/PD/02/02	 

Mixing operator	instruction 5.1.5 Ingredients used for each batch to be recorded in the mixing log 5.1.6 Any deviation from the recipe shall be approved by production supervisor or above	FR/PD/02/01	
	5.1.7 When the dough is ready, it is transferred manually by trolley to the hopper from which it passes via metal detection system and then it is conveyed automatically to sheeting/gauging.	WI/PD/02/16	
Cutter Operator	**5.2 Sheeting /gauging** *5.2.1* The dough is passed through presheeter /sheeter on laminator to get compact, continues sheet to spread across the width of reduction rollers. *5.2.2* The continuously processed sheet is laminated into several layers. *5.2.3* In some cases flour/fat sprinkles between layer before gauge reduction. *5.2.4* The layer processed dough is then pass through 3 sets of gauging rollers to attain compact dough spread sheet with desired thickness.		

Cutter Operator	**5.3 Cutting** 5.3.1 The dough sheet is passed under the cutting roller which produces the desired shape, size, surface design and docker holes. 5.3.2 Between the cut pieces there is a network of dough known as cutter scrap which is lifted away and returned to the laminator for recycle with fresh dough. This process is detailed in the cutter Work Instruction 5.3.3 In some cases the cut dough pieces are sprinkled with topping application before being baked. 5.3.4 Then the operator will check the weight as per the product parameters and will record it in the cutter logbook 5.3.5 The cut dough pieces are then passed through oven, with the help of traveling oven band..	WI/PD/12/01 FR/PD/12/01	

Responsibility	Process description	references	Process Picture
Oven Operator	**5.4 Baking** 5.4.1 The cut dough pieces are baked in different heating zones to achieve desired moisture, color, size, shape & thickness. The machine operation is detailed in the Oven Operation Work Instruction. 5.4.2 In some cases vegetable oil is sprinkled on the products surface. 5.4.3 At the oven exit, the operator will check the product color based on the approved color chart, product weight, dimensions and thickness. 5.4.4 All these measurements will be recorded on the oven log book.	WI/PD/12/02 FR/PD/12/02	 
Packing Operator	**5.5 Cooling** 5.5.1 After the product being passed through the necessary quality checks the biscuits transferred via a long cooling conveyor to packing section 5.5.2 At the end of cooling conveyor the biscuits are channeled into lines and stacked before being passed to the automatic loader which feeds the biscuits into machine slugs. **5.6 Packing** 5.6.1 The products are flow-packed and end sealed in cavanna machine. 5.6.2 The date code must be printed on every packet to ensure product traceability. 5.6.3 Machine operation is carried		 

	out based on cavanna work instruction. 5.6.4 All quality checks such as weight, sealing and date code etc. should be recorded on packing control sheet as per frequency determined in the Quality Plan.		
	5.6.5 The packets are filled automatically in cartons by OPM robot machine. In some cases the packets are filled in display boxes (coded). Then they are filled in outer cartons. 5.6.6 The cartons then passed through sealing machine where date and shift code is also printed. 5.6.7 Then cartons are palletized manually on the pallet and they are transferred to FGW after being labeled.	WI/PD/12/04 WI/PD/12/03 FR/PD/12/03	

6 ASSOCIATED DOCUMENTS:

Silo Control Room Work Instruction – WI/PD/02/01
Dough Mixing Work Instruction – WI/PD/02/02
Sheeting & Cutting Work Instruction – WI/PD/12/01
Metal Detector Work Instruction – WI/PD/02/16
Biscuit Oven Operation Work Instruction – WI/PD/12/02
Cavanna Operation Work Instruction – WI/PD/12/03
OPM Robot Machine Work Instruction - WI/PD/12/04
Biscuit Dough Mixing Log – FR/PD/02/01
Cutter Control Chart – FR/PD/12/01
Oven Control Chart – FR/PD/12/02
Packing Control Chart – FR/PD/12/03

Appendix C Line 12 work instructions (WI)

1. PURPOSE & SCOPE:

The purpose of this work instruction is to outline the procedure for mixing biscuit dough. This work instruction applies on lines1 &12 only.

2. EQUIPMENT REQUIRED:

- Weighing scale – platform type

3. REFERENCES :

- Standard Product Recipes

Special Reminder	Instructions & Explanations	Process Picture
GMP guidelines apply Wear hand Protection for healthy production Hair nets must be worn at all times Dough control sheet Ingredient system hoist SOP DUST MASK MUST BE WORN IN THIS AREA	**4.1 Mixing Stage1** 4.1.1 Weigh all ingredients required for each batch as per the recipe 4.1.2 Inform Silo Operator for product change over 4.1.3 Check that mixer is clean ,Switch on the mixer 4.1.4 Start cold water circulation through mixer jacket to regulate temperature. 4.1.5 Load 1st stage ingredient into the mixer (as per product recipe) 4.1.6 Close the Mixer and unload sugar from batching hopper. 4.1.7 Mixer will start automatically after sugar discharger completed. 4.1.8 Open the mixer once the mixing has stopped **4.2 Mixing Stage2** 4.2.1 Load 2nd stage ingredients into the mixer. 4.2.2 Close the mixer 4.2.3 Unload water from the batch hopper. 4.2.4 Mixer will start after water discharge completed. Open the mixer when mixing stops.	  

	4.3 Mixing Stage3 4.3.1 Add enzyme, acidulate, fibers ,nut, seeds (as per the recipe) 4.3.2 Close the mixer 4.3.3 Discharge the flour from batching hopper 4.3.4 Mixer will start automatically after flour discharge completed. 4.3.5 Mixer will stop after final mixing set time is over. 4.3.6 Unload the mixed dough into the dough bowl. 4.3.7 Tilt the dough into the dough hopper. 4.3.8 Unload prepared dough into dough hopper on other side & the mixer. 4.3.9 Inform cutter operator about dough preparation. Enter all mixing data in the log sheet (FR/PD/02/01).	

1. PURPOSE & SCOPE:

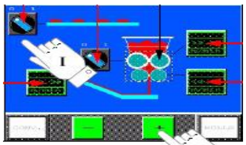
The purpose of this work instruction is to outline the procedure for biscuit dough laminating and cutting on Line 12.

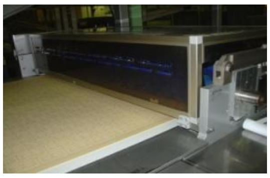
2. EQUIPMENT REQUIRED:

- Weighing scale

3. REFERENCES :

- Product Parameter.

Special Reminder	Instruction & Explanations	Procedure Picture
GMP GMP guidelines apply Types of hand protection (Healthy production)	**4.1 Start up** 4.1.1 Switch on the main electric panel board. 4.1.2 Select the machine in group /individual mode from monitor panel. 4.1.3 Select the recipe from monitor panel 4.1.4 Check and ensure whole machine thoroughly for trouble free operation.	 
 Hair Must Be Contained	**4.2 Laminating** 4.2.1 Stop pre sheeter roller of laminator & start machine in group mode to fill up the dough into the laminator hopper. Wait till the hoper get filled up to the limit set.	 
 D K MUST E WORN IN THIS AREA	**4.3 Gauging** 4.3.1 Start pre sheeter roller of laminator for flow of dough through machine 4.3.2 Adjust the pressure, feed controller & roller gaps etc to achieve compact spread sheet with desired thickness for cutting.	

	4.4 Cutting 4.4.1 Lift the cutter pressure roller up, to start dough sheet cutting .Adjust the pressure & speed of cutter to set the cutting operation. 4.4.2 In some products where topping is required, start sprinkler & maintain the quantity. 4.4.3 Adjust the cutter speed according to baking time to ensure that distance between biscuits on the band is maintained. 4.4.4 Adjust gauge roller and cutter to ensure that the dough weight and size reach standards. 4.4.5 Adjust the swivel panel to maintain equal gaps on the side of oven band. 4.4.6 Inform the oven operator that the dough is ready for baking.	 

1. PURPOSE & SCOPE:

The purpose of this work instruction is to outline the Procedure for Operating the oven in line 12.

2. EQUIPMENT REQUIRED:

- Vernier Caliper
- Weighing Scale
- Biscuit gauge monitor

3. REFERENCES :

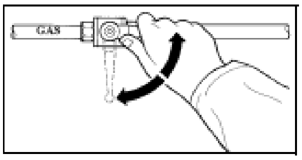
- Product Parameter

4. PROCEDURE :

<table>
<tr><th>Special Reminder</th><th>Instructions & Explanations</th><th>Procedure Picture</th></tr>
<tr><td rowspan="2">GMP GMP guidelines apply

Wear hand Protection for healthy production


Hair nets must be worn at all times


DUST MASK MUST BE WORN IN THIS AREA</td>
<td>4.1 Start-up
4.1.1 Turn the power switch on.
4.1.2 Open the gas supply valve
4.1.3 Search main menu
4.1.4 Select mode into Automatic
4.1.5 Put the cycle Automatic start
4.1.6 Switch on all the zone burners
4.1.7 ensure that they are lit on. If not , make them on manually by pressing ignition button situated near each burner.
4.1.8 Select the Actual Recipe
4.1.9 In case of cracker where oil sprinkler requires, fix this sprinkler m/c in line, start heater and maintain oil sprinkling quantity.</td>
<td rowspan="2">


</td></tr>
<tr><td>4.2 Process monitoring
4.2.1 Keep constant monitor on biscuit appearance, dimension, and thickness & make record of it.
4.2.2 Adjust oven temperature according to the product and baking speed to ensure that the moisture specification is achieved
4.2.3 Any product not meeting standards must be rejected at oven exit immediately.
4.2.4 If any non-conformance persists, the leadman or Shift Supervisor must be informed.
4.2.5 Enter reading in the Biscuit Oven Process control Sheet (FR/PD/ 02/04)</td></tr>
</table>

	4.3 Shutdown 4.3.1 Go to main menu 4.3.2 Select the mode into shut down time 4.3.3 Close the gas supply valve	

1. PURPOSE & SCOPE:

The purpose of this work instruction is to outline the process of running the Cavanna flow wrapping packing machines on Line 12.

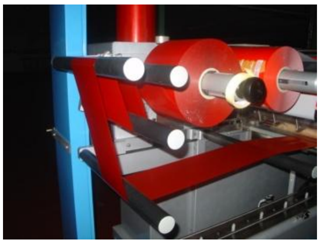
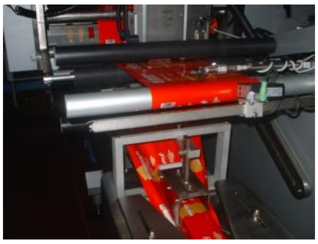
2. EQUIPMENT REQUIRED:

- None

3. REFERENCES :

- Standard Product Specifications

4. PROCEDURE :

Special	Instructions & Explanations	Process Pictures
GMP GMP guidelines apply Wear hand Protection for healthy productio n  Hair nets must be worn at all times  DUST MASK MUST BE WORN IN THIS AREA	**4.1 Start-up** 4.1.1 Switch on the power, on panel board 4.1.2 Check all emergency buttons at different location on machine. 4.1.3 Ensure that all the emergency button are deactivated 4.1.4 Push the RESET buttons and press the automatic buttons to make the ZERO settings. 4..1.5 Select the required product recipe on the screen 4.1.6 Wait till the temperature reaches the required settings. 4.1.7 Load the wrapper on the spindle and check the sensor. 4.1.8 Load the tear tape roll and adjust its position. 4.1.9 Set the correct date code as per requirement 4.1.10 Make film centering and check the date code 4.1.11 Switch on the automatic mode and then the loaders will start placing the product on slugs. 4.1.12 When the product goes through flow pack machine check the packs sealing quality (end and longitudinal). Make adjustment if required. 4.1.13 These products are passed through end sealing m/c. check its quality – adjustment if required. 4.1.14 Inform the line lead man to start the line.	  

	4.5 Process monitoring 4.5.1 Check the sealing and date coding continuously during production running. 4.5.3 Check the packet weight, dimensions and record into packing log.	

	NATIONAL BISCUITS & CONFECTIONERY CO
	PRODUCT PARAMETERS
	MIXING AREA
	DOCUMENT No: PP/12/01

Product Name:	Product configuration			Product Code:
TEA BISCUITS	Pack	Display	gm	310207 310847
	4	8	100	
	24	-	100	

Appendix D Tea Biscuit Product Parameters (PP)

Stage #1 Slow: 5min, Fast: 2min			
	unit	Std	Tolerance
Sugar (Pulverized)	Kg	70	± 0.5
Shortening Dough Fat	Kg	72.5	± 0.5
Skimmed Milk Powder	Kg	14	± 0.25
Vanilla Flavour	gm	210	± 5
Butter Flavour	gm	700	± 10
Salt Powder	Kg	1.8	± 0.1
Lecithin	gm	420	± 20
Liquid Glucose	Kg	7	± 0.5
Invert Syrup	Kg	7	± 0.5
Biscuit Dust	Kg	28	± 5
Silo Dust	kg	16	± 5

Stage # 2 Slow: 2 min, Fast : 2 min			
		Std	Tolerance
Water	Kg	100	± 4
Ammonium Bicarbonate	Kg	8.5	± 1
Sodium Bicarbonate	Kg	3.78	± 0.2

Stage # 3 Slow: 2 min			
		Std	Tolerance
Flour	Kg	336	± 5
Sodium Metabisuphate	gm	420	± 50

Prepared By:	Verified By:	Approved By	Revision No	Date of issue	Page #
Factory Manager B&W	QA Manager	Operations Manager	0	23/12/2006	1 of 6

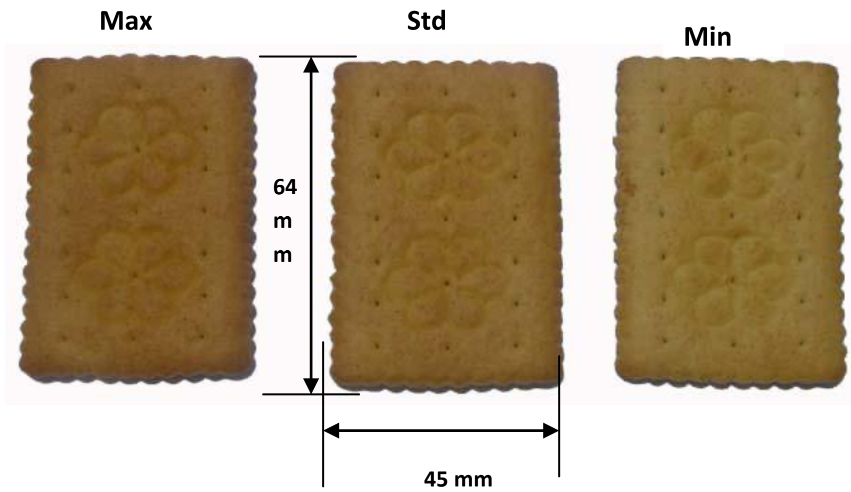
	Target	Tolerance
Dough Weight for 17 Biscuits	**127 gm**	**± 5 %**

Total Batch Weight kg	666.3

Prepared By:	Verified By:	Approved By	Revision No	Date of issue	Page #
Factory Manager B&W	QA Manager	Operations Manager	0	23/12/2006	1 of 6

	NATIONAL BISCUITS & CONFECTIONERY CO
	PRODUCT PARAMETERS
	BAKING AREA
	DOCUMENT No: PP/12/01

Product Name: TEA BISCUIT	Product Code: 310207,310847



		Unit	Target	Tolerance
Dimensions:	L	mm	64	± 2
	W	mm	45	± 2
Thickness		mm	6.35	± 0.2
Packet Net Weight:		gm	100	± 3
Stack Length :			108	± 2
Biscuit/packet:			17	± 1
Baking Time :	4:45 min :sec			
Biscuit/mts:	14x22			

Oven Temp ◦c				
Heater	Zone 1	Zone 2	Zone 3	Zone4
	180	215	188	173
Tolerance		+ 35		-10

Packet		Unit	Target	Tolerance
Dimensions:	L	mm	64	±2
	W	mm	45	±2
Stack Length	TH	mm	108	±5
Net Weight:		gm	100	±5
Wrapper Reel Width			250	±2
Wrapper Cut-off			171	±1
Production capacity\min\2 mc	217			
No. of Biscuits/Packet	17±1			

Display Box	L	W	H
Dimensions (mm) :	221	135	94

Carton	L	W	H
Dimensions (mm) ±1 :	282	226	196
No. of carton/hr	407		

Prepared By:	Verified By:	Approved By	Revision No	Date of issue	Page #
Factory Manager B & W	QA Manager	Operations Manager	0	23/12/2006	2of 6